The feeding ecology of the otter on three Northumbrian watersheds

Pautard, Nicola Jane

THE FEEDING ECOLOGY OF THE OTTER ON THREE NORTHUMBRIAN WATERSHEDS

NICOLA JANE PAUTARD

DEPARTMENT OF ZOOLOGY
UNIVERSITY OF DURHAM
SOUTH ROAD
DURHAM

A THESIS SUBMITTED TO THE UNIVERSITY OF DURHAM IN PART CANDIDATURE FOR THE DEGREE OF MASTER OF SCIENCE IN ECOLOGY.

1980

ABSTRACT

The diet of the otter on three Northumbrian rivers was assessed using spraint analysis. A total of 167 spraints were collected between March and June 1980, 80 from the North Tyne, 32 from the Blyth, and 55 from the Wansbeck-Font. Spraints were analysed using keys, photographs and reference collections, and where possible back calculations of fish size were attempted.

Results showed that fish formed the majority of the prey intake, mammal and bird occurrence were rare. The North Tyne showing the greatest variety in prey species taken. Eel were found to be the major fish prey taken on the North Tyne and Blyth, and bullhead on the Wansbeck-Font. In general, similar size prey species were taken on the three watersheds, and seasonal data suggests a reduction in crayfish, amphibia, Cyprinidae, trout, and perch in the summer compared to the spring diet. The results show no evidence of competition for food between mink and otter on the North Tyne.

CONTENTS PAGE

CONTENTS PAGE

CHAPTER 1.0

INTRODUCTION

The European otter, Lutra lutra Linnaeus is a member of the family Mustelidae (order Carnivora), fifteen species of which constitute the subfamily Lutrinae. The typical fish eating river otters all belong to the genus Lutra. The other groups comprise the clawless otters Aonyx and Amblonyx which feed on crabs and molluscs and the sea otter Enhydra which is almost entirely marine in its habits (Corbet and Southern 1977.)

DISTRIBUTION

Otters are distributed throughout most of the world with the exception of Australasia, Madagascar, and the Arctic and Antarctic regions. The European otter, Lutra lutra, has a fairly wide range and occurs throughout Europe and into North Africa and Asia, north of the Himalayas, including Japan. The Irish population of otters according to Corbet and Southern (1977) can be recognised as a distinct sub-species, L.lutra roensis on the basis of darker colouring on the upper body and a lesser extent of white on the throat. In Britain otters are now regarded as a rare and endangered species and are absent in their distribution from industrial areas of Southern Wales, the northern coastal strip of Wales, most of the Midlands, Central and Southern England, and from parts of the central lowlands of Scotland. O'Conner et al (1977) suggests that both the numbers and the range of otters has been reduced substantially during this century,fortunately through the action of conservation groups the decline decelerated during the 1960's. In 1978 the otter was added to Schedule 1 of the Conservation of Wild Creatures and Wild Plants Act 1975, which made it illegal to hunt, kill or persecute otters. The theories as to the possible causes of the decline of this animal in Britain will be discussed later.

GENERAL DESCRIPTION.

The otter is primarily a terrestrial mammal which has become adapted to utilizing the aquatic environment as a source of food. It is one of Britains largest carnivores, adult males growing to approximately 1.2 metres in length and weighing 10 Kg, and females 1 metre in length and considerably lighter at 7.5 Kg in weight. Harris (1968) states an exceptional case of an otter which was 1.8 metres in length and weighed 12.3 Kg. The body of the otter is described by Corbet and Southern (1977) as being elongate with short legs, a flattened head with small ears and a broad muzzle with prominent whiskers. The tail or rudder is long and tapers from a thick base, and forms approximately one third of the total length of the animal. Below the base of the tail are situated two small scent glands which emit a white secretion, this was thought to be linked with the sexual behaviour of this Mustelid (Gorman, Jenkins and Harper 1978). The feet are palmate with five widely separate toes on each. The strong interdigital webs aid swimming, and on land the tracks or 'seals' are characterised by the absence of a heel mark. The spacing of 'seals' on land is described by Corbet and Southern (1977) as 36cm when walking, 50cm at a gallop, and 80-100cm when bounding.

REPRODUCTIVE BEHAVIOUR.

Otters become sexually mature in their second or third year. Although it is known that the animal may breed at any time of year, (Harris 1968) spring births are most usual. The gestation period lasts 61-62 days, and there are usually 2-3 cubs in the litter. Stephens (1957) states that in exceptional cases there may be as many as five cubs in the litter. The breeding holt where the cubs are born is lined with reeds, grass and moss, and the young are raised entirely by the female. Development of otter cubs is slow and Erlinge (1967) found that they stayed with the female for 9-12 months in the study areas in Sweden.

Bitch otters have been observed (Harris 1968) teaching the young to swim at the age of 2-3 months when they possess the adult waterproof coat. Dispersal of the family usually occurs in the summer and therefore it has been postulated by Erlinge that the female breeds once every second year, at least in Sweden.

HABITAT REQUIREMENTS.

The precise habitat requirement of the otter is unknown, but Macdonald, Mason and Coghill (1978) believe that habitat 'breakdown'(categorisation) gives a reasonable representation of the otters requirements. Otters may be found in and around large rivers, and on productive lake systems, especially where cover is provided by reed beds. Sheltered coasts and coastal marshes also provide suitable habitat types. Erlinge (1972) states that the optimum habitat for the otter exists under eutrophic conditions (high nutrient), and sub-optimal habitats are found in oligotrophic waters (low nutrient). Ideally the river should be greater than 5m in width, plenty of cover, particularly ash and sycamamore, which provide large root systems for lying-up places (hovers) and holts, and bramble and reeds which conceal the animal during daytime. MacDonald et al (1978) study of otters in western England and eastern Wales showed that areas supporting otters had relatively more bankside vegetation, a greater density of trees, and potentially more lying-up sites and holts, for which ash and sycamore appeared to be particularly important. The food provisions in the habitat are of primary importance, although the actual density of fish required to support the otter is not known. The presence of cover and undisturbed habitat is important since otters appear to be particularly vulnerable to disturbance, the changes caused by riparian clearances and tree felling, and disturbance caused by anglers and other recreational activities, have caused the decline of the otter in many areas of Britain, despite the apparently adequate food supply.

Otters are mainly nocturnal in habit, although they may hunt at dawn and dusk. In areas totally devoid of disturbance, otters can be observed during the daytime. Otter dens or holts are found in a variety of places, including holes under river banks or tree roots, disused rabbit burrows or open nests, known as couches (Hewson 1969) which are concealed in reeds or thickets. To avoid confusion in the present study, sleeping places regularly in use will be referred to as holts, and areas suitable for lying-up but unsuitable for long term use will be referred to as hovers. In a study of the River Teme catchment by MacDonald et al (1978) it was found that of the potential holts and lying-up sites recorded, 60% were in areas where otters were thought to be resident. Potential holts were always under trees, mainly sycamore and ash. Otters do not excavate their own holts but often rely on the fluctuating river level to scour away the soil from bankside trees, revealing an open root network suitable for habitation. In areas where there is a shortage of potential holt sites, conservation groups have introduced artificial holts to encourage animals to become resident in the areas. Therefore in conclusion, the requirements of the habitat for otters to be present are:- an adequate food supply, water which is free from pollution, plenty of cover, especially along the river bank, and a minimum of disturbance.

TERRITORY AND HOME RANGE.

The otter is often described as a wanderer, having a more or less undetermined area of activity (Erlinge 1967a). Mammals living in a heterogenous environment may restrict their activity to limited areas known as home ranges. Erlinge (1967a) has studied extensively the range, density and territoriality of otters in Sweden and believes that territoriality of the otter benefits the species as a whole by enabling it to make the best use of available food resources. In Sweden, Erlinge found the average range of the dog (male) otter to be 15 Km, but to vary from 10-12 Km, the range is less for a bitch (female) with cubs, 7 Km around lakes and 10 Km along streams and rivers. It is possible that British otters may show slight behavioural differences which could cause some variation in results compared to the Swedish data. Shepherds' (1937) study of otters in Norfolk states that a dog otter may travel 15-20 Km a night. Home ranges vary seasonally as well as locally with regard to size, and the maximum extension of the range is determined by the topography of the region. Erlinge considered that feeding access to open water in winter is an important factor, influencing both the location and size of home ranges and food supply, and population density probably also influences the size of the home range. Home ranges are based on the fundamental requirements of the family group. Stephens (1957) states that families with cubs are rarely found less than 8 Km apart. Variation in the distance is mainly due to topographical conditions, individual qualities and the presence of other otters, especially dog otters (Corbet and Southern 1977). Otters usually have several hovers and holts scattered around the home range, these are often centred around the breeding holt. Hewson and Kruuk (1978) found holts spaced at an average distance of 1.1 Km in marine habitats. In Sweden Erlinge (1968a) found that the population in winter consisted of 30-40% resident territory holders, 30-40% temporary residents and 23-38 % young of the year. Densities of otters were calculated to be one animal per 0.7 - 1 Km^2 area of water, or one animal per 2-3 Km length of lakeshore, and one otter per 5 Km length of stream. In Britain, Stephens (1957) quotes densities of one otter per 10 Km (twice the distance of Swedish otters) based on observations from hunts, and West (1975) estimated the densities of otters in Suffolk also to one otter per 10 Km of river.

The otter displays territorial behaviour which is shown by signal activity, dispersion patterns and movements of the animals. The boundaries of territories are overlapping zones which are marked by scented excrement or spraints which serve as olfactory signals, forming a major role in social communication. Corbet and Southern (1977) state that communication by sprainting activity can be clearly correlated with territoriality and population density, and that intense scratching and signalling occurs at the overlap of adjacent ranges. Dog otters' territories primarily have a sexual significance and the territories of family groups secure access to feeding areas. Hewson and Kruuk (1978) also postulate that the territorial system might well be a function of resource defendability. Disturbance of the habitat by human activity fragments the animals territory and may restrict its range, thus affecting the otters ability to find sufficient food, hovers or suitable breeding sites. Veen (1975) in work carried out in Northern Holland, found that there were some places where otters were more frequently found. These places were centres of territories with paths radiating from them. The centres tended to be in the least accessible places (for humans) amongst dense vegetation and were found to be 3-4 Km apart. Veen also concluded from his research that otters cover most of the home range by walking rather than swimming. MacDonald et al (1978) located 5-6 resident territories in their studies of the River Tene catchment, this was thought to be very much below the carrying capacity of the habitat. Since territory size varies in relation to resources, it was calculated that for the Tene catchment the habitat could support 20-40 pairs of otters. MacDonald and Masons (1976) study in Norfolk estimated a total population of 17 pairs in the county, this was calculated by studying the activity at sprainting sites, the number of spraints being related to the density of the population. There was also an estimated population of 18 pairs in Suffolk. On average MacDonald and Mason found one pair of otters per 45 Km of river, or a density of one pair per 31,500 ha (Norfolk). Assuming that dog otters have a home range of 10-15 Km, the maximum carrying capacity of the area was calculated to be 52-77 pairs. Cranbrook (1978) estimated that Suffolk could support 40-50 pairs of otters if the habitat did not deteriorate further. The preliminary results of the 1973-79 Mammal Society Otter Survey indicated that the otter is still fairly widespread but as mentioned previously, they are comparatively scarce in some parts of Britain.

DECLINE AND CONSERVATION.

The beginning of the otters decline started in some areas as early as the middle of the nineteenth century and is thought to have been initiated by persecution and increased river pollution from industrialisation. The major decrease has been recognised by the Mammal Society as starting from 1957, and continued until 1967 when the decline was much less marked, and the population stabilized in many areas.

Establishing the exact cause of the British decline in otters is difficult and most authors (Hewer, 1974; Cranbrook, 1978) suggest a combination of factors including habitat destruction, human disturbance, pollution and over-exploitation of the species as some of the causes.

Otter hunting was originally cited as the cause of the decline, but since the sport has been practised for over 800 years, it appears unlikely that it could have caused such a rapid and drastic decrease in the otter population. The decline took place so quickly and simultaneously over the whole of Britain, that it suggests a sudden change in circumstances around 1957. Chanin and Jefferies (1978) suggest that pollution was the most likely cause for the fall in the population. The toxic organochlorine pesticides, mainly D.D.T and Dieldrin have been implicated as causing catastrophic and sublethal affects in many populations of birds and mammals, and the decline of the otter in 1957 correlates with the introduction of Dieldrin in sheep dips 3 years earlier. These toxic chemicals would reduce the otter population by acting on the reproductive ability of the animal. Despite the ban on the use of organochlorine, the otter population showed no signs of recovery in later years. Since the decline, habitat destruction and increased disturbance has occurred along most British waterways, thus making it difficult for the animal to reoccupy areas where it had previously been present.

It is not known whether the presence of an established mink population impairs the ability of the otter population to re-establish itself. It appears that the minks greater ecological amplitude and tolerance of mans activities enables them to exploit habitat inimical to the otter (Wise 1978). The effect of the competition between mink and otter will be discussed later in greater detail with regard to feeding.

Other causes of the decline have been considered by many researchers but although important on a local scale, they are unlikely to be significant in causing the overall decline. Habitat destruction may now limit the otter to areas of suitable 'cover' where disturbance is minimal. In response to the problems of disturbance and habitat destruction, the Vincent Weir Trust and the Fauna Preservation Society have set up the Otter Haven Project in July 1977, whose function is to establish areas for otters, by agreement with landowners, where the destruction of the habitat and disturbance are minimised.

SPRAINT DESCRIPTION.

Much of the information about the ecology of otters, their numbers, distribution, range and diet, can be obtained from spraint analysis. The faeces (spraints) produced by otters are cylindrical and may be from 2-8cm long and about 1 - 1.5cm in diameter (Jones, Bray and Wood 1979). The colour varies from grey through shades of greenish-brown to black, and are described as having a sweet smelling aroma, similar to that of new mown hay. The faeces, when fresh, are contained within a thick tube of mucus enclosing a residue of hard, more or less indigestible matter, the mucus protects the bowel of the otter from damage during excretion. Elmhirst (1938) postulated that because of the condition of fishscales and minute crustacea found in many spraints, digestion must be very rapid. Gorman (pers.comm.) found that a diet of lamprey took 4 hours to be egested in a captive otter.

Weir and Bannister (1973) found sprainting sites to be favoured where the animal habitually left the water. Otter sprainting sites occur where there is plenty of cover amongst trees and bushes. Islands, promontories, the inside corners of river bends and the confluence points of rivers are also places where spraints may be found. Otters sometimes scrape together sand mud or vegetation to make a heap, onto which they deposit a spraint or a drop of anal scent. As mentioned previously, spraints are used as territorial markers and indicate the presence of otters, especially on regularly used paths. The sprainting sites are therefore usually prominent and are often on large boulders close to, or in, the stream or river. In the absence of boulders, raised 'seats' are commonly used, especially in coastal and marshy areas. Hewson and Kruuk (1978) found that otters which they studied visited sprainting sites soon after leaving the water, and after defecating or urinating, rolled on their backs on a patch of grass nearby. Hewson and Kruuk also found that the number of spraints decreased away from the holt, which further indicates the importance of spraints for social communication. Ottaway and Potter (1976) state that it is possible that visiting otters can tell the length of time a scent had been deposited, as also the age, sex, and reproductive condition of the animal which deposited it.

In a survey of otters in Wales by the Nature Conservancy Council 1977-78 (eds Jones et al 1979)it was found that an otter may produce up to 20 spraints a night.

ADAPTATIONS.

In his studies of the feeding habits of otters in Loch Park,Scotland, Hewson (1973) found that the animal spent more time below the water than above when hunting. Whilst diving the otter was observed to arch its back and dive with the tail in line with the body as it went down. In water, the forepaws are used for swimming on the surface, and in turning. Under water, otters have been recorded swimming at speeds as high as 10 - 12 Km/Hr. In marine habitats otters have been observed swimming considerable distances to their foraging areas, in some cases 700m, and may spend over two hours hunting in an area 50 x 100m,Hewson and Kruuk (1978). Hewson found that the mean duration of the dive was 14.6 seconds, with a longest dive of 22 seconds and a mean surfacing time of 5.7 seconds. Corbet and Southern (1977) state that the otter can travel 400m under water without surfacing, which must be an exceptional case, since most authors quote much smaller distances. The dives are accompanied by brachycardia (Harris 1968) and when alarmed the animal may remain submerged for up to four minutes. Green (1979) investigated the otters use of sight and mechanical perception using vibrissae, by shaving the muzzle of the animal. The efficiency of catching prey was found to fall by 3.6 - 4.1 times in dark conditions, whilst without vibrissae, in dark water, the efficiency of predation fell 20.9 times, compared with clear water conditions. Green therefore concluded that under clear conditions the otter relies on sight, whilst in the dark, the animal depends on the less effective sense of mechanical perception. It is not known if the otter uses its sense of hearing beneath the water.

PREDATORY BEHAVIOUR.

Erlinge (1968b) recognised several elements in the hunting behaviour of otters, the tracking of prey was considered appetitive behaviour, preceeding the more specialised appetitive behaviour, chasing the prey and the consummatory action of catching and eating. The abundance of the prey animals in the habitat was found to appreciably affect the sequence of catching. Otters are rarely observed lying in wait for their prey (Erlinge 1968b) and active fish prey are more easily detected than sedentary fish.In hunting, the otter usually swims beneath its prey,since the fish cannot see below and are siezed. Waterbirds are usually grasped by the legs from below the water. The otter siezes the fish in most cases by the belly, and prey greater than about 10 cm in length were observed by Erlinge to be taken ashore by the otter, whilst smaller fish were usually eaten in the water. The fish is grasped between the otters forelegs and eaten with a chewing motion, since the otter can only rotate its jaws in one plane. Fish have been found by Erlinge (1968b) and Ryder (1955) to be caught in an inverse relationship to their ability to escape; and fish of intermediate size, 15-17 cm, were taken before smaller specimens, due both to the otters preference and the greater vulnerability of fish of this size. Rejection of prey is thought by Erlinge to be primarily influenced by its outer covering. Fish with large scales may prove more difficult than a smaller specimen of the same prey species. Ryder (1955) states that the otter captures fish in proportion to their abundance, thus less abundant fish are taken less frequently. However, population size is not the only factor determining the extent of predation, habitat, mobility, body size and behaviour with regard to shelter, all determine the vulnerability of fish species (Erlinge 1968b).

FEEDING HABITS.

In recent years increased research into the ecology of otters has revealed important information about the diet of otters in various regions and habitats of Britain. The areas of research have been in Devon (Wise, 1978; Chanin, 1976) the Somerset levels (Webb 1975), Wales (Stephens, 1957; O'Connor, 1977,) Norfolk (Weir and Bannister 1973), Scotland (Elmhirst, 1938; Jenkins et al, 1979; Hewson, 1973; South Uist (Twelves) and the Shetlands (Watson), both unpublished, Northern Ireland (Fairley and Wilson 1972). Other studies on the feeding ecology outside Britain include Sweden (Erlinge 1967b; 1968b), United States (Greer, Montana, 1955; Sheldon and Toll, Massachusettes; 1964;Toweill, Oregon, 1974; Lagler and Ostenson, Michigan 1942,)and in Africa (Rowe and Rowe 1977).

In Britain, there appears to be an absence of data about the otters diet in some areas, notably in Northern England where the present study was carried out. The majority of dietary investigations are by sprsint analysis, although digestive tracts have been examined as a comparison when available (Toweill, 1974; Stephens,1957).

Harris (1968) states that "Otters do not appear to be highly selective feeders but show a seasonal distribution of prey species taken". The diet appears to vary depending on the prey species which are available in the habitat. Most studies show that fish constitute 70 - 90% of the total food intake, which one would expect since the otter is highly adapted to the aquatic environment. Otters also take a variety of birds, mammals, amphibia, crustacea, and insects when available, including moorhen, coot, duck, widgeon, plover, pheasant, gull, grebe, heron, vole, mice, rabbit, hare, frog, lizard, snake, mussel, crayfish, beetle, and larvae. When the normal food fails, otters have been known (Stephens,1957; Harris, 1968) to take lambs, suckling pig and poultry. Some spraint analyses have even shown the presence of mink fur in the otters faeces (Harris 1968). Otters have been observed consuming carrion and Harris states that in some cases otters have been observed eating the bark of aquatic trees.

Most species of fish are eaten but the more easily caught coarse fish are particularly favoured, possibly due to the lack of large scales and sharp spines. Results of previous research into dietary intake will be discussed later with comparison to the present study. There is some argument as to whether otters kill more fish than they can eat, but this probably only occurs where the prey is exceptionally abundant. Otters are usually thought not to store food, but the animals have been observed placing the remains of fish beneath stones in rivers, this may be to attract eels as the favoured prey. In some areas large numbers of salmonids appear to be taken (especially Scottish rivers), but these are usually very small specimens and since otters live at low densities, it seems unlikely that the animal should prove a pest to anglers. Some authors (Ryder 1955) have suggested that predation by otters may benefit the trout population of a river by removing the less desirable, competitive and noxious fish, or destroying eels which eat trout spawn. Erlinge (1967b) concluded that food composition varies with the habitat and that otters show a similar diet in similar environments. Prey species were found to suffer predation in relation to abundance. In Sweden, otters were shown to have a marked seasonal variation in diet which is caused by a variation in abundance and/or behaviour of the prey populations. Some prey species are only seasonal and intense predation occurs when prey populations are easy to catch, for example, amphibians suffer heavy predation during periods of inactivity. Predation may be directed against the young of the species, this is especially noticeable on birds. Erlinge (1967b) states that food preference is of no importance since it is more economic in energy terms to hunt available and vulnerable species, rather than to expend energy hunting possible favourite food items.

The actual consumption of food depends partly on the type of food, but an average intake may be 1 - 1.5 Kg per day (Stephens 1957). Otter predation may work toward some sort of balance between the prey populations (Erlinge 1967b).

The otter possesses distinct ecological adaptations which make it suited to its feeding niche of the aquatic habitat, although it does also utilise the terrestrial habitat for hunting, but to a much lesser extent.

COMPETITION.

There is much dispute in Britain over the extent to which mink and otter compete for food. Corbet and Southern (1977) state that the feeding habits of the two mustelids overlap by 60 - 70 % as both animals exploit the more easily available prey. In Sweden, Erlinge (1969) has found that the otter subsists for much of the year almost entirely on fish, whilst the mink, being less aquatic, feeds on birds and mammals as well as fish. The study also indicated that about one third of the fish taken by otter were specimens exceeding the maximum size of fish generally caught by mink, the feeding habits of the two mustelids overlapped by 30 - 40 %, Chanin (1976) found on the river Teign, that competition between mink and otter took place since the otter had no alternative food resource to exploit when mink were feeding in the same niche. Akande (1972) found that in Scotland, fish formed 49% of the minks diet, but considered that the difference in prey size and greater use of the terrestrial environment reduced competition between the mink and otter. In the area studied, the mink appears to be occupying a vacant feeding niche. This was also hypothesised by Day and Linn (1972) in their study of mink in England and Wales where birds appeared to be the major food, and fish to be of only seasonal importance. Erlinge (1972b) regards the otter as being dominant to mink, the otter being a superior exploiter of habitat favouring its specialisation and that the minks exploitation of food resources in common is reduced by interference from the otter. However, in Britain competition between mink and otter not only includes the feature of food resource rivalry, but also that of habitat, mink being more tolerant of disturbance and reduction of cover, and therefore enabling the population to increase, whereas the otter is restricted to areas with adequate supplies of food and specialized habitat requirements.

METHODS OF DIETARY ANALYSIS.

Erlinge (1968b) states that the analysis of diet by the presence or absence of prey items in spraints gives a reasonably accurate picture of the relative importance of different food categories, and that American researchers (unnamed) have found no more prey species using gut content analysis. It has been argued by Lagler and Ostenson (1942) that volumetric analysis of stomach contents gives a better representation of the relative importance of the various food items than do samples obtained from the intestines. They further state that spraint analysis is least valid in this respect because digestible remains are accumulated. Spraint analysis was the only method of investigation available in the present study and therefore it is difficult to postulate whether certain prey items are being omited from the analysis. The study is primarily concerned with the diversity and size of prey taken and their relative importance on the various watersheds. Volumetric assumptions cannot be made from spraint analysis since the number of bones and vertebrae do not directly correlate with the quantity of prey taken. This possible source of error will be discussed later with regard to the results found in this study.

The two methods available for spraint data analysis are, frequency of occurrence of prey items, and bulk analysis, which also includes relative estimated bulk.

Frequency of occurrence has been used by Erlinge (1967b, 1968b), Webb (1975) Chanin (1976) and Wise (1978) and indicates the fraction of the total number of different prey species represented by a particular prey type. The majority of researchers into otter diet have included frequency of occurrence in the analysis of their results as it is thought to give a reasonably true picture of the relative importance of the different food categories (Erlinge ,1968b), but is also a relatively quick method to use, an important consideration when the spraint sample size is very large. There are two major disadvantages using this method. Jenkins et al (1979) have suggested that frequency of occurrence of undigested items in faeces over-estimates the importance of items which occur frequently but in very small quantities, and under-estimates those items occurring occasionally but in large quantities. Englund (1965) also considered that the more important an item, the greater the possibility that it will be represented in the spraint. Therefore an increase in importance of the prey in the diet may not be accurately reflected in frequency of occurrence. The second disadvantage concerns the proportion of flesh to bone in the different prey species. This may vary considerably and the large prey may therefore be under-represented if only the flesh and scales are eaten leaving the backbone; also soft-bodied prey such as earth worms may be overlooked in spraint analysis since they have only a minute proportion of indigestible parts (chaetae). Conversely, prey species with a large proportion of indigestible parts e.g., arthropods, may tend to be overestimated in the analysis.

An alternative method which may be applied to spraint analysis involves volumetric estimates of prey items present, known as the Bulk Estimate (Weir and Bannister 1973; Wise 1978; Jenkins et al 1979).

Estimates of bulk give an indication of the relative proportion of the prey items without the necessity of weighing the individual prey remains. Jenkins et al (1979) proposed that bulk estimates were more accurate in terms of a true representaion of the importance of prey in the otters diet, but has the major disadvantage of being very time consuming.

Relative estimated bulk was a method used by Lockie (1959) in his study of fox diet, and is the proportion of the total bulk of spraints formed by one particular prey item. Although this method is useful because it involves no calculation of weights, Lockie found the method to be unsatisfactory as it gave inconsistent errors. His alternative method of percentage weight of undigested matter did give consistency in error and therefore allowed conversion factors to be applied.

The bulk estimate is the proportion of the identifiable remains of the spraint by weight which is represented by a particular prey species, and indicates the proportions of the prey in the diet with respect to their volume. Wise (1978) found in her feeding study of mink, that bulk estimates were much more accurate than frequency of occurrence. The application of conversion factors takes into account the fact that a particular prey species remains may form a large proportion of the bulk, such as feathers, but may only form a small proportion of the weight of the spraint, therefore counteracting the inherent errors in bulk analysis. Conversion factors were calculated by Lockie (1965), Day (1968), Akande (1972) and Wise (1978) by feeding trials on various carnivores, notably weasel, mink and fox. The conversion factor for each prey was calculated as :-

$$\frac{\text{Weight given} - (\text{weight left} + \text{weight lost due to evaporation})}{\text{Dry weight of scats produced.}}$$

The conversion factor multiplied by the bulk estimate gives the original weight of prey ingested.

OBJECTIVES IN THE PRESENT STUDY

The aim of the present study is to investigate by spraint analysis the feeding ecology of the otter on three Northumbrian watersheds, the North Tyne, the Blyth, and the Wansbeck-Font from March to July. It seems unlikely that over such a short period of time seasonal differences will be recognised, but it is hoped however to show differences in both size and species of prey taken between these areas, these being realted to prey availability to the otter in the various habitats. The prey species that are present on the watersheds will be examined and a comparison made ~~to~~ with the species found to be predated by the otter.

CHAPTER 2. STUDY AREAS

2.0 INTRODUCTION.

Three main watersheds were chosen for this study, the river North Tyne and some of its tributaries, the river Blyth, and the rivers Wansbeck and Font, which form the Wansbeck-Font watershed. The rivers were selected primarily because they indicated that there were otter present, and also in some cases the presence of mink and disturbance of the habitat was a consideration. Secondly, access to the river was important as was the landowners permission to survey areas of private land. Distance from the University to the study area was an economic consideration and allowed all the rivers to be sampled on the same day. Otters are known to be present on the rivers Aln and Coquet in north Northumberland but unfortunately the travelling distance was too great for a comprehensive study to be made of those river systems.

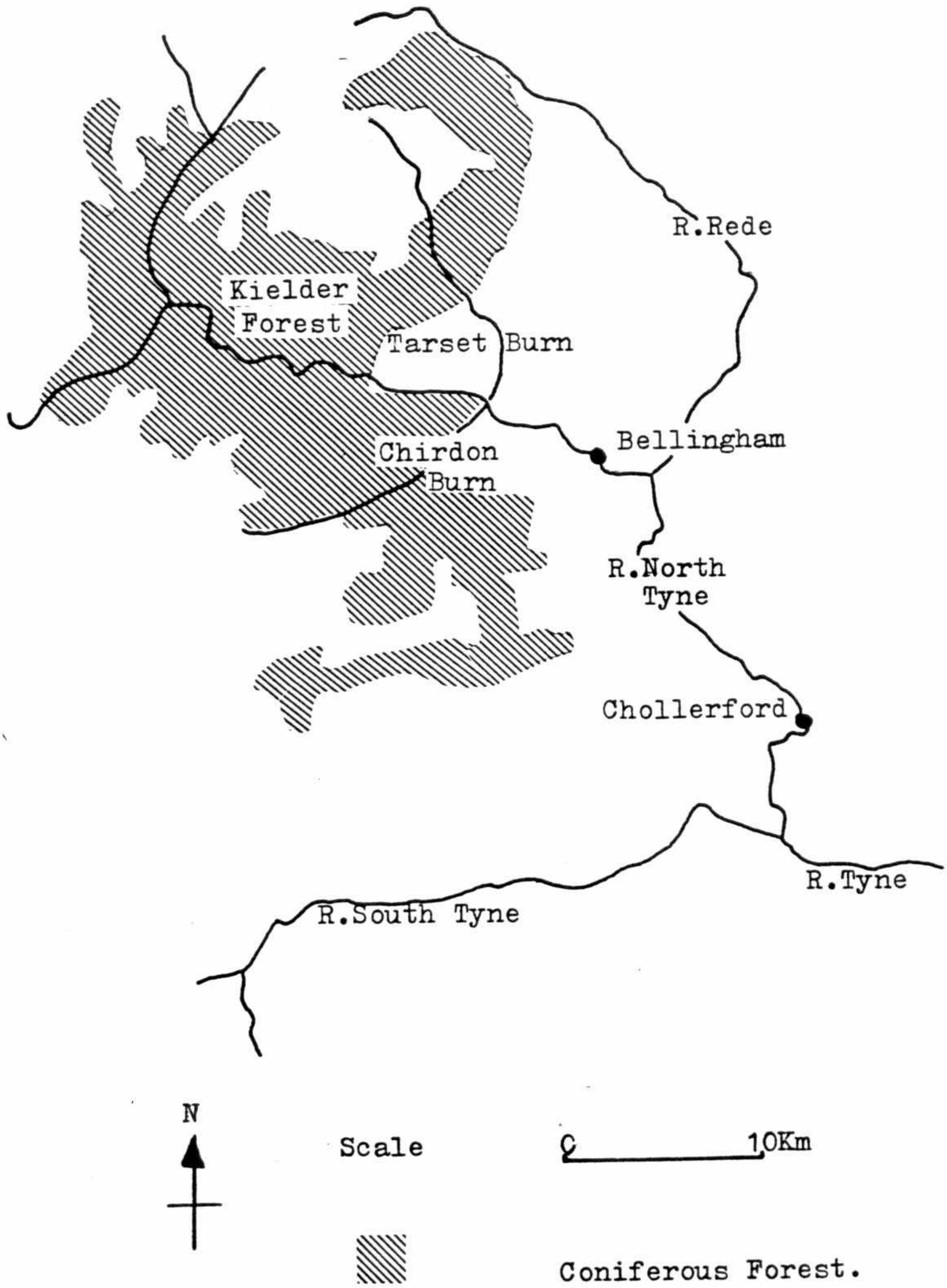
2.1 NORTH TYNE

The river North Tyne rises in Kielder Forest situated in the Border Hills between Northumberland and Galloway. It flows in an easterly direction and turns southward near the village of Bellingham and joins the South Tyne a few kilometres further down river, just west of the town of Hexham. The main river Tyne flows eastward and reaches the North Sea at Tynemouth. Figure 1, shows the course of the North Tyne river and the sites visited.

2.1.1 RIVER CHARACTERISTICS.

The North Tyne is very variable in width. At Bent House Bridge (GR NY 782856) 12 Km from its source where the water is faster flowing, the river width is approximately 7 - 10m. Downstream, 24 Km at Chollerford, the river is approximately 15m in width, although it narrows considerably after passing Wall Mill. The height of the river varies markedly during periods of heavy rainfall in June and July, the water was observed to rise nearly 30 cm in less than one hour. At such times peat stain is

Fig 1. THE NORTH TYNE WATERSHED.



washed down the river from the forested areas, thus giving the water a dark brown colour and characteristically acid nature. The variation in discharge of the North Tyne for January to June 1980 is shown in Fig.2(a), the data was obtained from the Northumbrian Water Authority monitoring station at Tarset, (GR NY 776861). Unfortunately data was only available January to June and the graph omits the heavy discharge of flow during July. The absence of heavy rainfall during the very warm period of April and May is indicated in low discharge rates for these months as well as small changes in the daily mean. The high maximum daily mean for February is possibly due to the high output of meltwater from the snow in the Border Hills.

2.1.2 SITE DESCRIPTION.

CHOLLERFORD.

Chollerford (GR NY 919707) was the most important study site on the North Tyne. Both sides of the river were explored from Chollerford Bridge (GR NY 919707) to Wall Mill (GR NY 916684) for spraints and other signs of otter, (tracks, pathways, hovers etc.), a distance of approximately 5 Km on each bank. The area on the western bank of the river from the jetty to opposite the mill, Fig. 3, and Plates 1(a), (b) and (c) was visited regularly to investigate the frequency of sprainting sites, which are marked in Fig.3. Otters have been known to breed further upriver in an area of woodland and shallow ponds near to Chollerford Bridge, but the holt now seems to have been abandoned. There appears to be no holts in use along the stretch of river studied, but several hovers were found (Fig.3) and they showed evidence of fresh spraints in the entrances.

BELLINGHAM.

Spraints were found near Bellingham Bridge (GR NY 834834) on only two occasions. The sprainting site was a few hundred metres upriver from the bridge on the west bank on stones at the edge of the river. Two spraints were also found on a large fallen tree which overhung the water.

Fig 2. RIVER FLOW CHARACTERISTICS 1980

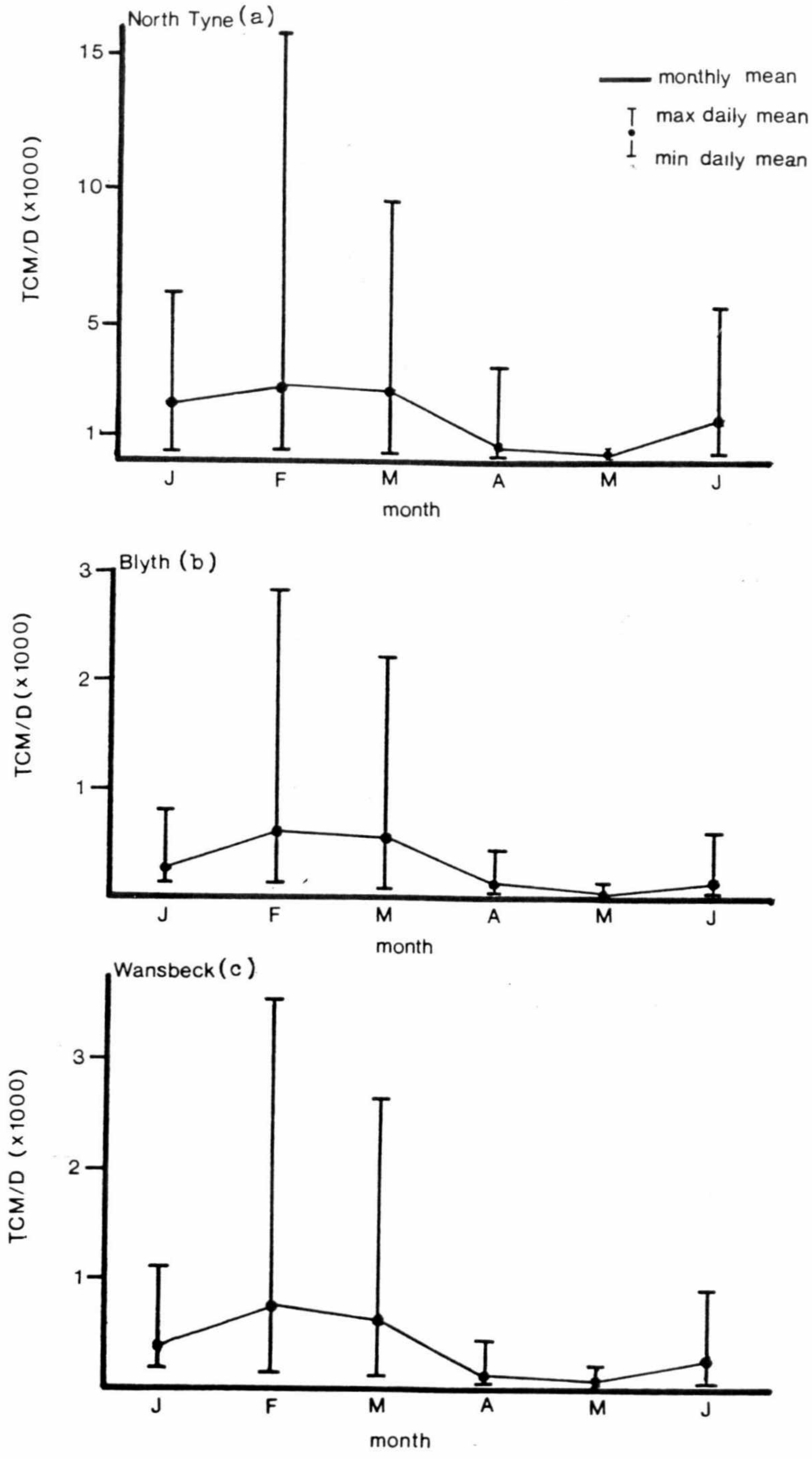


Fig 3. THE NORTH TYNE RIVER,CHOLLERFORD SITE.

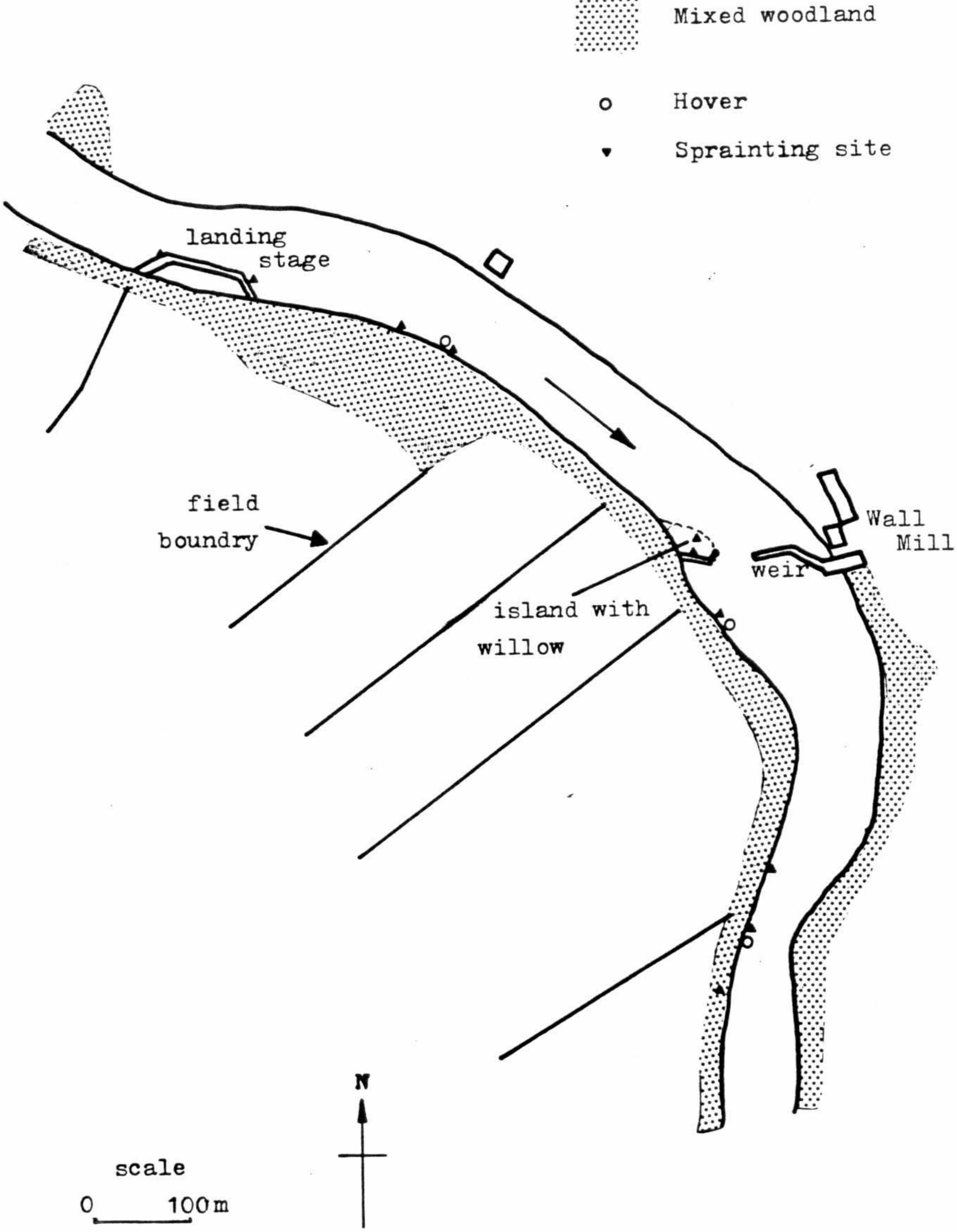


Plate 1(a)

Plate 1(b)

Plate 1(c)

The North Tyne flowing southwards, taken from the west bank, Chollerford site.

The North Tyne, looking north. Chollerford.

Small area of land opposite Wall Mill, on the west bank.
The vegetation consists of a dense cover of willow (Salix sp.).

OTHER SITES.

Spraints were obtained from these on only one occasion, the sites being tributaries of the North Tyne, Greenhaugh (GR NY 788859), Benthouse Bridge (GR NY 782856), and Chirdon Burn (783851). The samples from Lea Hall Crags, Errington Burn and Hawksley Burn, were found in April 1979 by a previous researcher.

2.1.3 HABITAT.

Habitat structure is an important element determining both the presence and movement of the otter in an area. Unfortunately no quantitative estimate of vegetation cover as a structural component could be made and qualitative estimates made were purely subjective, however they do indicate the general habitat type on each of the rivers.

Four main elements of habitat structure may be recognised (MacArthur and MacArthur 1961), the ground layer, the herb layer, the shrub layer, and the tree canopy layer. A vegetation height of approximately one metre would provide adequate cover for the otter to remain undisturbed, which may be provided by long grass, herbage and shrubs. Trees are of little significance in terms of cover since a deciduous tree canopy is very variable throughout the year. Trees, however become important when considering holt and hover sites. 'Cover' for the purpose of this study describes a relatively dense enclosure of vegetation, either of grasses, herbs, or shrubs, and 'open' refers to an impression of lack of shrubs or grasses which may conceal the otter. With regard to the habitat around sprainting sites, cover was used to imply that some form of vegetation either canopies the sprainting site or is very close (less than 1m). The general impression of a habitat may appear one of cover, but the actual position of the sprainting site may be in the open.

In general terms, the habitat type of the North Tyne appears fairly open. At the main study area at Chollerford (Fig.3) there are patches of woodland, with trees near the bank being approximately 11m apart. The tree species are mainly sycamore (<u>Acer</u> sp.) and beech (<u>Fagus</u> sp.) with some oak (Quercus sp.) and alder (Alnus) present. On the site marked on the map there was a herbage layer, mainly of grasses of the genera Phragmites, Lolium and Agrostis and ground flora including Centaurea nigra and Lysimachia vulgaris. Over the North Tyne study area, from the bridge at Chollerford to the mill, there is a marked absence of bushes and thick cover and some areas next to the river were very open. At the Chollerford site, the west bank falls at an angle of approximately 45° from the field above to the river. Here, overhanging trees and exposed root systems can provide suitable hovers, but it appears unlikely that they are extensive enough and probably are too far away from the water to serve as holts. The root systems are primarily used by rabbit, and mink have been observed using them as dens (A.Rosser pers. comm.). There was easy access along the river bank, therefore disturbance, especially by anglers is probable.

Opposite the mill on the western bank a small area of land (approximately 10m long by 8m wide) projects into the river. Otter spraints were found here on a number of occasions (Plate 1 (c)). The vegetation comprised a thick mass of shrub willow (Salix sp.), and there was evidence of a small otter run or pathway through the thick cover with spraints being deposited both along the pathway and on a stone at the waters edge.

At sites further up the North Tyne, the habitat also appeared fairly open and vulnerable to disturbance. At Bellingham, the sprainting site was close to a small wooded area, but the actual spraints were found on rocks that could be clearly seen from the road bridge and the opposite bank.

Because of lack of sufficient cover, it appears that on the North Tyne, the otters were only passing through, using large stretches of the river for travelling. Evidence from the present study suggests that the sites where the animals spend most of their time are more likely to have a greater amount of cover and an absence of human activity. These areas were not found due to problems of access to the land and the time involved searching the whole watershed area.

2.1.4 PREY DIVERSITY.

INTRODUCTION.

It was originally hoped that quantitative estimates could be made of the prey populations, however due to the short duration of this study, and lack of equipment, this was not possible.

FISH.

The abundance and species diversity of the fish population in a river can be assessed either by netting or by electrofishing.

Unfortunately no information could be found on abundance, but data on species diversity was obtained from the Northumbrian Water Authority and local angling clubs, this gave an indication of the species that may be predated by the otter. Game fish present in the North Tyne are the brown trout and sea trout (Salmo trutta) and the salmon (Salmo salar). Other coarse fish include eel,(Anguilla anguilla), flounder (Platichthys flesus), gudgeon (Gobio gobio), dace (Leuciscus leuciscus), roach (Rutilus rutilus), stone loach (Noemacheilus barbatulus),three-spined stickleback (Gasterosteus aculeatus), bullhead (Cottis gobio)minnow (Phoxinus phoxinus), brook lamprey (Lampetra planeri)some perch (Perca fluviatilis)and pike (Esox lucius).

According to the Northumbrian Water Authority Fisheries Report 1979, the large game fish come into the North Tyne during January and February, the low water levels during the summer prevent migratory fish entering the upper reaches of the Tyne. In 1979 there was a stocking programme of 37,000 salmon parr and moults into the main North Tyne, 3,500 into Chirdon Burn and 1,000 into Greenhaugh Burn. Trout stocking was also high; 16,350 7.5 - 32,5cm brown trout; 25,500 20 - 35cm rainbow trout (Salmo gairdneri) 350 15 - 20cm brook trout and 310 coarse fish (species unspecified).

Two electrofishing surveys were carried out by the Teesdale Unit of the F.B.A. headed by Dr E.M.Ottaway in the vicinity of Kielder Water in 1978/79 (unpublished report). In the upper reaches of the North Tyne trout were found to be the most numerous and widespread of the species studied. Five other species were also caught, the stone loach, minnow, three-spined stickleback, eel and brook lamprey. Second to trout, eel was the most frequently occurring species, and although they were never found at great densities, the biomass of eels per square metre was 'appreciable'. Eels appear to be able to survive in the small becks and narrower areas of the river, whereas species such as the adult salmon are confined to deeper water. In July 1978, the survey found the greatest frequency of trout to be under one year old, (0+) and 4 - 6cm in length. In the lower reaches 2+ year fish were 21.65cm, 3+ year fish were 24.20cm, 4+ year fish were 29,40cm, and in July 1979 5+ year fish were 37.90cm. Pyefinch (1955) states that in the North Tyne 94 % of salmon are 2 year old migrants, salmon less than one year old average between 4 - 6cm in length. In the middle reaches of the North Tyne (mean width site being 25m) a salmon density of 0.036 fish/m^2 was found with an estimated population of 1,459 salmon in the area. Population density can be estimated by multiplying the calculated population size by the area fished.

The largest density of stone loach was found to be 1.5 fish per m^2 on Pleshetts Burn. These fish fill the same ecological niche as bullhead, which were absent from the study area. Minnow were extremely numerous, (large shoals) but stickleback were never caught in large numbers. Brook lamprey were found in the main river system with the greatest density of 0.2/m^2. Stone loach were aged by otoliths (calcareous particle found in inner ear of fish). The age size classes of stone loach captured can be seen in Table 1. Most stone loach found on the North Tyne were from the 2+ age group measuring 8-10cm in length. Densities of the fish population were calculated for the main North Tyne

Table 1. AGE SIZE CLASSES OF STONE LOACH ON THE NORTH TYNE WATERSHED.JULY 1978.

AGE (years)	UPPER TYNE mean length cms.	LOWER TYNE mean length cms.
1+	6.91 ± 0.13	6.16 ± 0.005
2+	9.96 ± 0.07	8.14 ± 0.005
3+	11.04 ± 0.07	10.20 ± 0.09
4+	12.48 ± 0.17	- -

Table 2. POPULATION DENSITY OF FISH ON THE MAIN NORTH TYNE(GR NY 656903)

Fish species.	Density of population/ m^2
Brown trout 0+	0.003
Other trout 0+	0.003
Salmon 0+	0.227
Stone loach	0.315
Minnow	0.093
Three spined stickleback	0.015
Eel	0.004
Lamprey	0.002-0.207

(GR NY 656903) and are shown in Table 2.

MAMMALS.

No trapping of small mammals was carried out but information from trapping by A. Rosser (pers. comm.) shows that wood mice (Apodemus sylvaticus) bank vole (Clethrionomys glareolus), water vole (Arvicola terrestris) and common shrew (Sorex araneus) were present in the North Tyne area at Chollerford. Large numbers of rabbit (Orytolagus cuniculus) are known to be presnt in the area, as are red squirrel (Sciurus vulgaris), rat (Rattus norvegicus) and feral farm cats (Felis sp.).

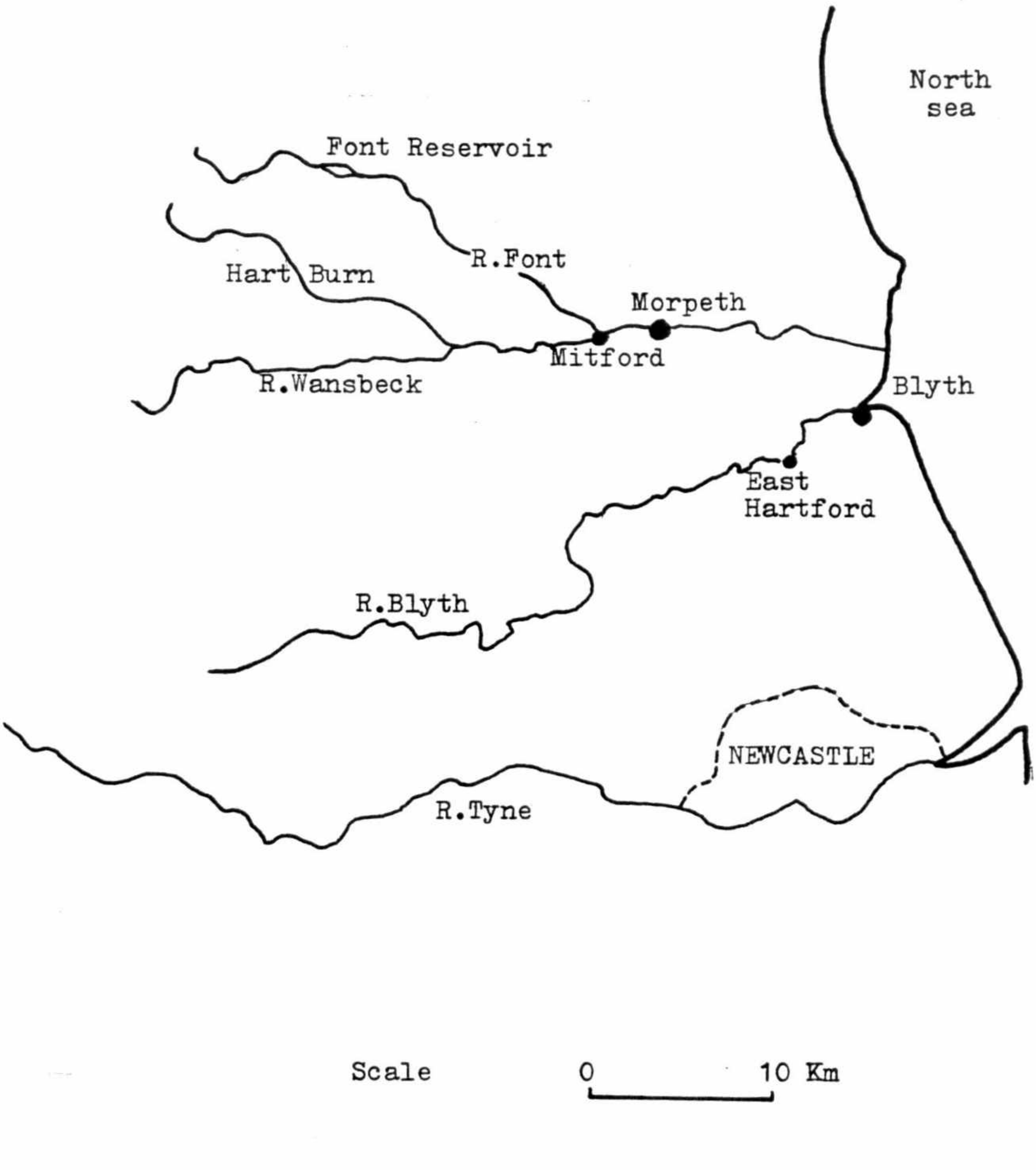
BIRDS.

The avian species on the North Tyne are very diverse and encompass a wide range of woodland and water birds, including; goosander (Mergus merganser), mallard (Anias platyrhynchos), coot (Fulica atra), moorhen (Gallinula chloropus), grebe (Tachybaptus ruficollis), heron (Ardea cinerea), dipper (Cinclus cinclus), kingfisher (Alcedo atthis), oystercatcher (Haematopus ostralegus), lapwing (Vanellus vanellus), greenshank (Tringa nebularia), redshank (Tringa totanus), common sandpiper (Tringa hypoleucos) , grey wagtail (Motacilla anerea), pied wagtail (Motacilla alba), pheasant (Phasianus colchicus), partridge (Perdix perdix), woodpigeon (Columba palambus), rook (Corvus frugilegus). There is a large rookery close to the Chollerford site. It is mainly the waterbirds that are at the greatest risk from predation, particularly the species which swim in the river, such as moorhen and duck, as they can be caught from beneath the water by the otter.

AMPHIBIA AND CRUSTACEA

In the shallower, sheltered areas of the North Tyne, toad and newt spawn was observed in May, so it seems likely that these species, including frog, would be common in the area. The absence of small becks at Chollerford makes the occurrence of crayfish unlikely, although they may be present further up the river at Chirdon Burn.

Fig 4. THE BLYTH AND WANSBECK-FONT WATERSHEDS.



2.2 BLYTH

The river Blyth rises in a region approximately 14 Km due east of the North Tyne. The Blyth flows eastward and turns northward in the area of East Hartford and flows out into the North Sea at the Blyth estuary (Fig.4).

2.2.1 RIVER CHARACTERISTICS.

The width of the river at Hartford Bridge (GR NY 242800) is approximately 10m, however the width varies considerably over the river, flowing eastward, as it meanders downstream. The variation in discharge of the river can be seen in Fig.2(b), the data was obtained from the Water Authority Hartford station. The graph shows a marked increase in discharge in February which falls off to a minimum in May, again like the North Tyne, reflecting the seasonal rainfall and periods of dry weather. The actual volume of discharge is approximately four times less than on the Tyne, due mainly to the size of the watercourse and the number of 'feeding' tributaries. On the river Blyth, the Geissbach site was regularly monitored for otter activity.

2.2.2.SITE DESCRIPTION.

GEISSBACH.

The Geissbach site was a stretch of the river Blyth which extended from Hartford Bridge (N2 242800) to a point opposite Owlet Hall (N2 254802), a distance of 2.5 Km. (Fig.5 and Plates 2(a) (b) and (c)). Otters have been known to be present in this area of the Blyth for many years (H. Watson pers.comm.), and there is evidence of a holt situated amongst large boulders next to the river (Plate 2 (c)). Although sprainting sites appeared to be very numerous on the first visit, repeated visits showed little evidence of re-use, possibly due to the otters moving upriver. It is doubtful whether the otters move any further downstream than East Hartford, since pollution of the river from a sewage works in this area has caused a marked reduction in both fish populations and the microfauna on which they feed.

Fig 5. RIVER BLYTH,GEISSBACH SITE.

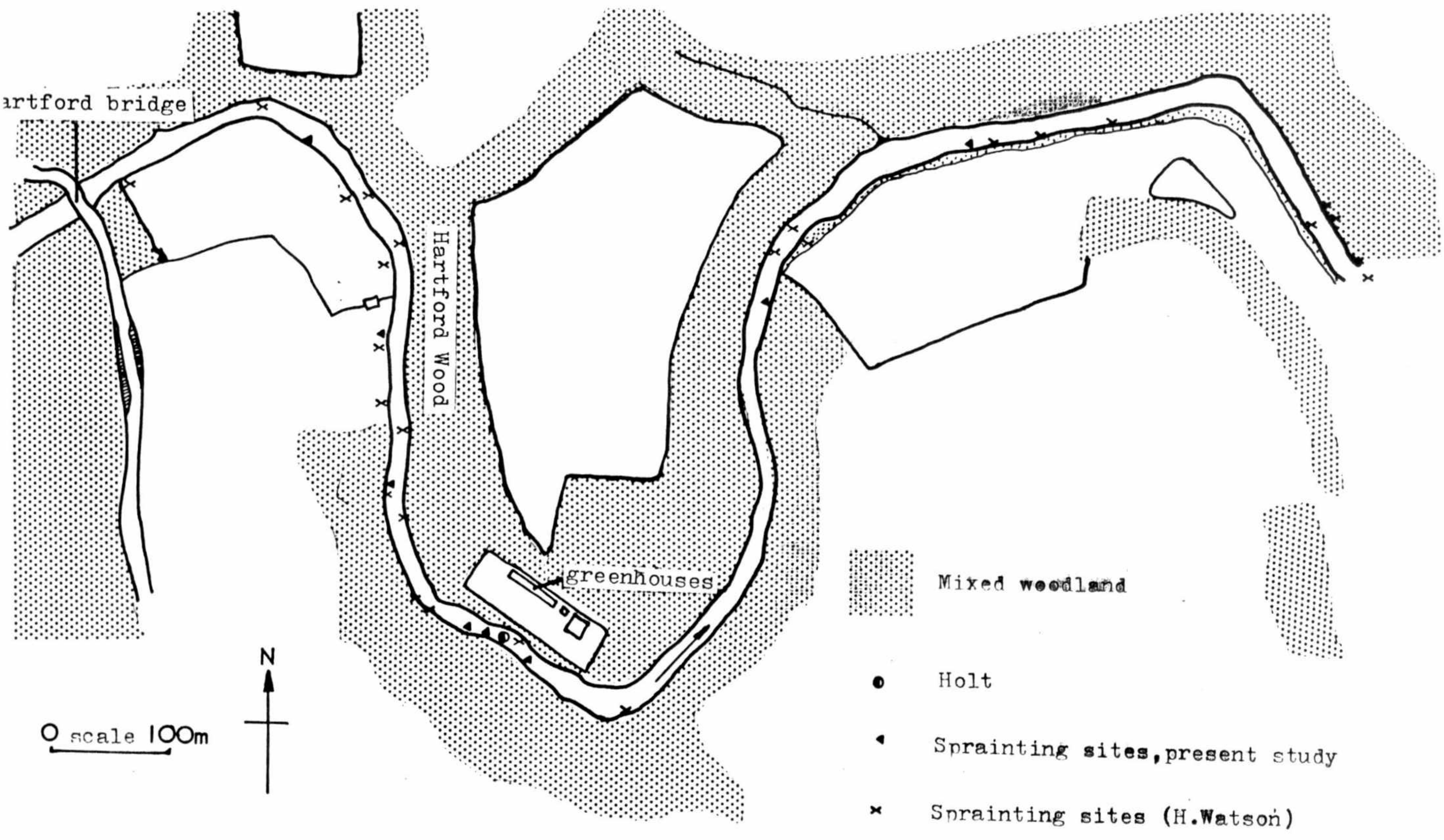


Plate 2(a)

Plate 2(b)

Plate 2(c)

The river Blyth, looking west.

The river Blyth, flowing east. Note the dense cover close to the water.

Area of the Blyth opposite the greenhouses. The holt is situated between the boulders on the right.

2.2.3 HABITAT.

The habitat type of the Geissbach site was, for the most part, classified as 'cover'. Apart from a few yards where the vegetation was open, the area was mostly covered by birch (Betula sp.), oak, sycamore and ash (Fraxinus sp.), with an average spacing of approximately 2.5m, although in places the trees were very close.

The bank of the river was very steep for much of the Geissbach site, with a cover of brambles and wood garlic (Allium ursinum), most of the surveying of the area had to be carried out actually from the river. Since the site was fairly inaccessible, the only disturbance appears to be from anglers, who tend to travel to their fishing areas via the fields behind the wooded stretches of the river.

The otter holt present on the river was situated in the bank opposite an area of greenhouses, so the animals must be able to tolerate some degree of human disturbance.

The upper reaches of the river near the bridge tended to be lacking in stones and boulders and here spraints were deposited on the ground. Despite the good cover, the vegetation surrounding the actual sprainting site was often classed as open since the boulders used were greater than one metre away from direct cover.

2.2.4 PREY DIVERSITY.

FISH.

The Blyth contains no migratory fish and is very limited in the fish species present in the lower stretches due to pollution. The fish species include trout, grayling (Thymallus thymallus), perch, roach, dace, gudgeon, eel, bullhead, three-spined stickleback, stone loach and minnow. On the Blyth coarse fish are more abundant in the 'close' season for trout fishing, that is, October to March. This is probably apparant because of the lack of game fish, therefore making coarse fish seem more abundant. In 1979, into the rivers Blyth, Font and Seaton Burn, 1,250 17.5 - 35cm brown trout, 1,000 35cm rainbow trout,800 coarse fish and 80 brook trout were introduced.

MAMMALS.

No mammals were observed at the Geissbach site, and unlike the North Tyne, there is a distinct absence of rabbit warrens along the bank. Some small mammal tracks were observed but recent rainfall made them unidentifable. Vole and mice are probably present in the area.

BIRDS.

Apart from woodland birds, the only species identified were mallard and moorhen. Other species such as heron, coot, dipper, and possibly some game birds may be present.

AMPHIBIA AND CRUSTACEA.

Large frogs (Rana temporaria) were observed in the study area. Toads (Bufo bufo) and newts are also probably resident.

Although crayfish were not actually found, there are many small burns and becks flowing into the Blyth which crustacea such as crayfish (Astacus fluviatilis) and fresh water shrimp (Gammarus neglegtus) may inhabit.

2.3 WANSBECK-FONT

The river Wansbeck rises further north than the Blyth and runs parallel to it, flowing eastwards. At the village of Mitford (GR NZ 174859) the Wansbeck is joined by the smaller river Font, which rises from Harwood forest in the north-west and flows in a south-easterly direction until it joins the Wansbeck (Fig.4). The Wansbeck continues eastward through Morpeth and finally out into the North Sea. The Wansbeck and Font belong to the same watershed and were considered together for the purpose of this study, since the fish species available for predation by the otter would be similar.

2.3.1 RIVER CHARACTERISTICS.

The width of the Wansbeck varies considerably along its course, but at the sites studied it averaged between 10-13m. The discharge from the Wansbeck for 1980 is shown in Fig.2 (c), the data was obtained from the Water Authority station at Mitford. The pattern of increased flow in February is also reflected at the Mitford station as it was on the previous rivers.

The Font is a smaller river both in width and rate of flow, the mean width being approximately 9m.

2.3.2 SITE DESCRIPTION.

MITFORD.

The site at Mitford (GR NZ 171856) is situated on the Wansbeck. Spraints were found regularly (although unfortunately not mapped) on a small area of stone downstream from the bridge (Plate 3 (a)) and at the bridge.

RIVER GREEN MILL.

River Green Mill (GR NZ 138848) is situated approximately 5 Km upstream from Mitford (Fig.6 and Plate 3 (b)). Surprisingly the main area where spraints were found was in close proximity to River Green Mill Farm, and it was stated by the owner that years ago they used to watch otters playing in the river outside the house. Unfortunately spraints were not regularly found at this site, probably because only one animal was using large stretches of the Wansbeck river, possibly being the same otter as was using the Mitford sprainting site.

No holts were found in the area, but hovers were observed.

MELDON BRIDGE.

Meldon Bridge (GR NZ 119851) is a small bridge over the Wansbeck, approximately 0.5 Km upstream from River Green Mill (Plate 3 (c)), and provides cover for regular use of the sprainting site. Numerous spraints were found on stones under the bridge on both banks, although many of them were only smears and contained no fragments for dietary analysis.

Fig 6. RIVER WANSBECK, RIVERGREEN MILL SITE.

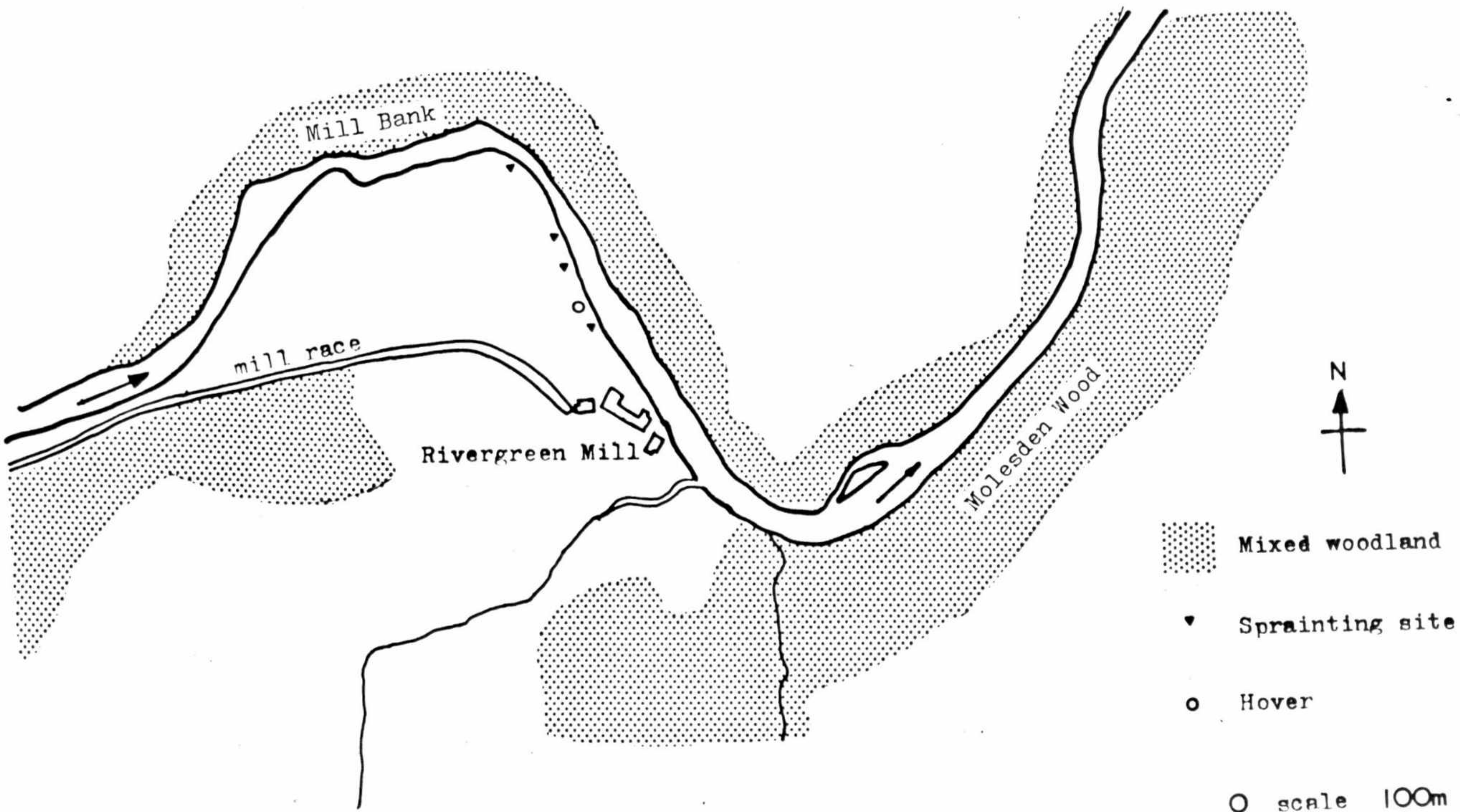


Plate 3(a)

Plate 3(b)

The bridge at Mitford.The river Wansbeck,looking west.

River Wansbeck,River Green Mill site looking downstream(east).

Plate 3(c)

Plate 3(d)

Meldon Bridge,river Wansbeck.Spraints were found on stones beneath the bridge.

River Font site.The river here is both shallow and narrow.

HARTBURN BRIDGE.

Hartburn Bridge (GR NZ 092860) was only visited once, but a total of eight spraints were collected from stones both beneath the bridge and close to it.

FONT.

The study site chosen was a stretch of the river Font situated between two fords (GR NZ 130889, and NZ 118894). Although many spraints were collected when the area was first visited, on subsequent visits only one spraint was found.

No definite hovers were identified, but the site studied appears to have excellent tree root systems exposed, which could provide hovers for the animals.

The river in the study area (Plate 3 (d)) was fairly shallow and most of the time spent searching for spraints was done whilst walking in the river.

2.3.3 HABITAT.

The habitat type on the Wansbeck and Font sites was intermediate between the habitat types of the other river systems studied. The vegetation was not as open as on the North Tyne, but was much less dense in cover than the Blyth.

However, analysis of the habitat type around sprainting sites showed that spraints were deposited much closer to vegetation than on the Blyth, where spraints were found away from vegetation. This may reflect the differing degree of human disturbance on the two rivers.

The tree species at Mitford were mainly sycamore and oak, and there was a distinct absence of suitable hover sites. Next to the river was a pathway regularly used by anglers and for recreation, and there was an absence of any shrub cover or long grass. The small island of stones used as a sprainting site did possess a small amount of grass cover which probably hid the animal from any direct disturbance. Possibly due to the fact that this area provides no suitable lying-up places or cover for the animal, it is likely that this stretch of river is only used when otters move through and forms no distinct centre of the home range.

River Green Mill comprises a slightly less disturbed habitat and also a greater proportion of cover, primarily bushes and brambles. The tree species are mainly oak, lime and sycamore, but these are mainly situated a metre or so from the bank. There is no public access to the River Green Mill site and there appeared to be very little disturbance through human activity.

The Font site when first visited appeared fairly undisturbed, but in July a campsite was erected adjacent to the river, which probably explained the absence of spraints on further surveys of the site. The vegetation is similar to that at River Green Mill, many trees overhang the bank, especially on the bends in the river where the flowing water has undermined the root sytems of the trees. A large badger set was observed at the site, but it seems unlikely that they would deter otters from becoming resident in the area. It is possible that the Font cannot supply enough food for the otter to utilise it as a major foraging area and therefore this area of the Font may be used as a subsidiary area to the Wansbeck. It is possible that this site marks the southern extension of an otters range from further upstream, and that human disturbance, lack of food, or possibly interaction with other otters in the area may restrict its movements.

2.3.4 PREY DIVERSITY.

FISH.

The Font and Wansbeck have no large coarse fish populations to speak of (R. D. Hall, Big Waters Angling Club, pers.comm.) fish in the Font are most likely to be bullhead, stone loach, three-spined stickleback, minnow, some trout, and eel.

In the Wansbeck, there are fewer bullhead and stone loach, and a greater population of trout than on the Font. The Wansbeck is supposed to have several runs of sea trout in late Autumn and the river was stocked with 5,000 13cm brown trout in 1979.

MAMMALS.

Rabbit were observed on both the Wansbeck and Font sites, but no other mammals were observed, although mice and vole are probably present.

BIRDS.

Moorhen, mallard and dipper were seen on the Font and probably also occur on the Wansbeck. A variety of bird species are probably present as on the Tyne, but many will only be passing through, and those of major importance will be the aquatic birds, juveniles, and injured birds which may be caught by the otter.

AMPHIBIA AND CRUSTACEA.

No amphibians were observed on the Font and Wansbeck, but they probably are present. Crustacea, especially crayfish, are likely to occur, mainly on the Font, since it is shallow and very stony in some stretches.

CHAPTER 3.

MATERIALS AND METHODS.

3.1 SAMPLING PROGRAMME.

It was originally hoped that each river site could be visited for spraint collection every two weeks, but unfortunately the infrequent use of the sprainting sites, and heavy rainfall during June and July, washing the spraints away, resulted in many of the visits being unproductive. When looking for spraints the whole of the river bank was searched, with the emphasis being on suitable substrates, e.g.,large stones, points of access to the river and possible hover sites. Spraints are characteristically 2 - 8cm long and approximately 1 - 1.5cm wide. When fresh the faeces are blackish in colour, turning to grey as they dry. In contrast, mink faeces (scats) are greenish to grey in colour, cigar shaped, and are often twisted in form. Spraints and scats may also be distinguished by their smell. Otter spraints which are described as smelling sweet and spicy are easily distinguished from the repugnant smell of mink scats. Fish vertebrae, spines and scales are usually evident in the spraint (Plates 4 and 5). On finding a spraint, the position of the site was marked on a map (1:2500 or 25.344 inches to the mile), and the immediate surrounding habitat recorded,as well as the substrate on which the spraint was found. Wherever possible, only a portion of the spraint was removed, and placed in a polythene bag and labelled with the site reference and date. A total of 167 spraints were found, 80 from the North Tyne, 32 from the Blyth, and 55 from the Wansbeck-Font watershed. At some sites, notably Meldon Bridge, there were many spraints, but these were only smears, and contained no prey fragments for analysis. On one occasion on the Font, white anal jelly was observed next to a spraint.

3.2 TREATMENT OF SAMPLES.

Spraints were examined intact to assess their age. Very fresh spraints were recognissble by the envelope of wet mucilagenous material; fresh spraints which showed no mucus but appeared black in colour and intact;

Plate 4.

Plate 5.

Plate 6.

Typical spraint location.

Detail of spraint showing the vertebrae present.

Three spraints after cleaning.The left spraint shows a contents of amphibian,centre,eel vertebrae and right crayfish exoskeleton which gives the spraint an orange colouration.


10 0 11 0 12 0 13 0 14 0 15 0 16 0 17 0 18 0 19 0 20 0 21 0 22 0
4 5 6 7 8
NPL DESIGN

old spraints were classed as those appearing greyish in colour and crumbly in texture. This classification is very tenuous since the condition of the spraint is dependent on weather conditions. A week of dry warm weather may make the spraint appear 'old', yet it may only have been deposited a few days. Spraints were aged to identify those which may have been deposited during the winter and therefore may have contained a different seasonal range of prey. No very old spraints were found, possibly because the majority were located in places which would normally be affected by climatic conditions. Hovers were the only potential sites for intact winter spraints; the spraints found deposited here were invariably fresh. It was not possible to quantify the age classification because of adverse weather conditions.

There are two major methods of separating the contents of a spraint. Oven drying the spraint and crumbling for examination of the contents has been used by Greer (1955), Erlinge (1969), Chanin (1976) and Wise (1978). This method has the advantage of being fairly quick to carry out and with a small likelihood of fragments being lost. The second method, used by Stephens (1957), Akande (1972), Weir and Bannister (1973) and Cuthbert (1973), involves washing the spraints and then sieving to separate the prey fragments before analysis. Both methods were tested, and the latter proved to be the most efficient process for the purpose of this study. It was found that dry analysis was difficult because of the large amounts of mucus and fine matter which obscured the diagnostic characteristics of the spraint prey content. Debris was collected following washing and showed only minute gravel to have been lost. It was possible that very small items such as worm chaetae may pass through the sieve, but it was unlikely that these would have been found anyway, since the majority of analysis was made using a binocular microscope. Each spraint was placed in a boiling tube containing water and a few drops of domestic detergent. This solution served to separate the prey fragments from the large amount of mucus which is produced during defaecation. Other solutions for the purpose of separation were tested, including a weak bleach solution, which was unsuitable as it damaged any hairs present, and a solution containing a Steradent tablet, which was unsatisfactory.

The spraints were left in the detergent solution for 24 hours, rinsed through a 40 μ sieve, oven dried at 50°C for approximately six hours, then weighed and placed in small labelled tubes for later analysis. Plate 6 shows the spraints after separation, each clearly illustrates the presence of different prey items, amphibian, fish and crayfish.

3.3 IDENTIFICATION OF PREY REMAINS.

Spraint contents were examined using a X10 binocular microscope.

3.3.1

FISH.

Fish were identified primarily by means of vertebrae, but scales and jaws were also used when present. Vertebrae were identified using a published key (Webb 1977), photographs (Wise 1978) and a reference collection of various fish species, including perch, trout, eel, chubb (Cyprinidae), stickleback, grayling and bullhead, The characteristics of the vertebrae of the fish species is shown in Fig.7. Fish scales and jaws were also used for identification and proved useful when vertebrae were absent or too damaged for recognition.

Scales can be used for calculation of age and length of the fish eaten, but the majority of scales examined were too damaged for accurate examination, or were from parts of the animals body where distortion of the scales caused spurious readings. Only scales from the region of the lateral line can be used for accurate assessment of fish age and length.

Fish size may be back calculated by using the centrum length of the vertebrae (Wise 1980). Both anterior and caudal vertebrae were used, but extreme anterior and posterior vertebrae were ignored, since they were

Fig 7. ILLUSTRATIONS OF FISH VERTEBRAE

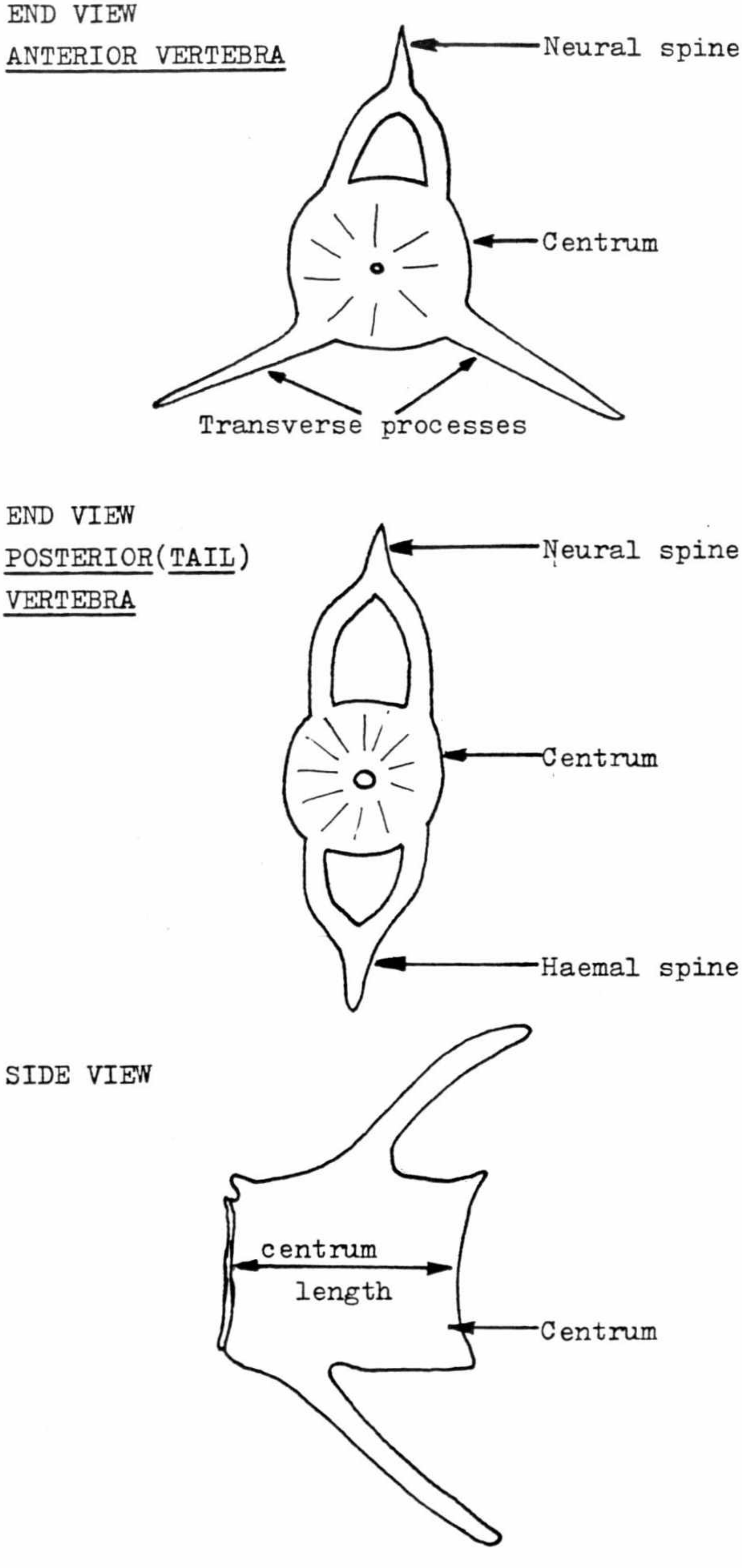


Fig 7.(cont.)

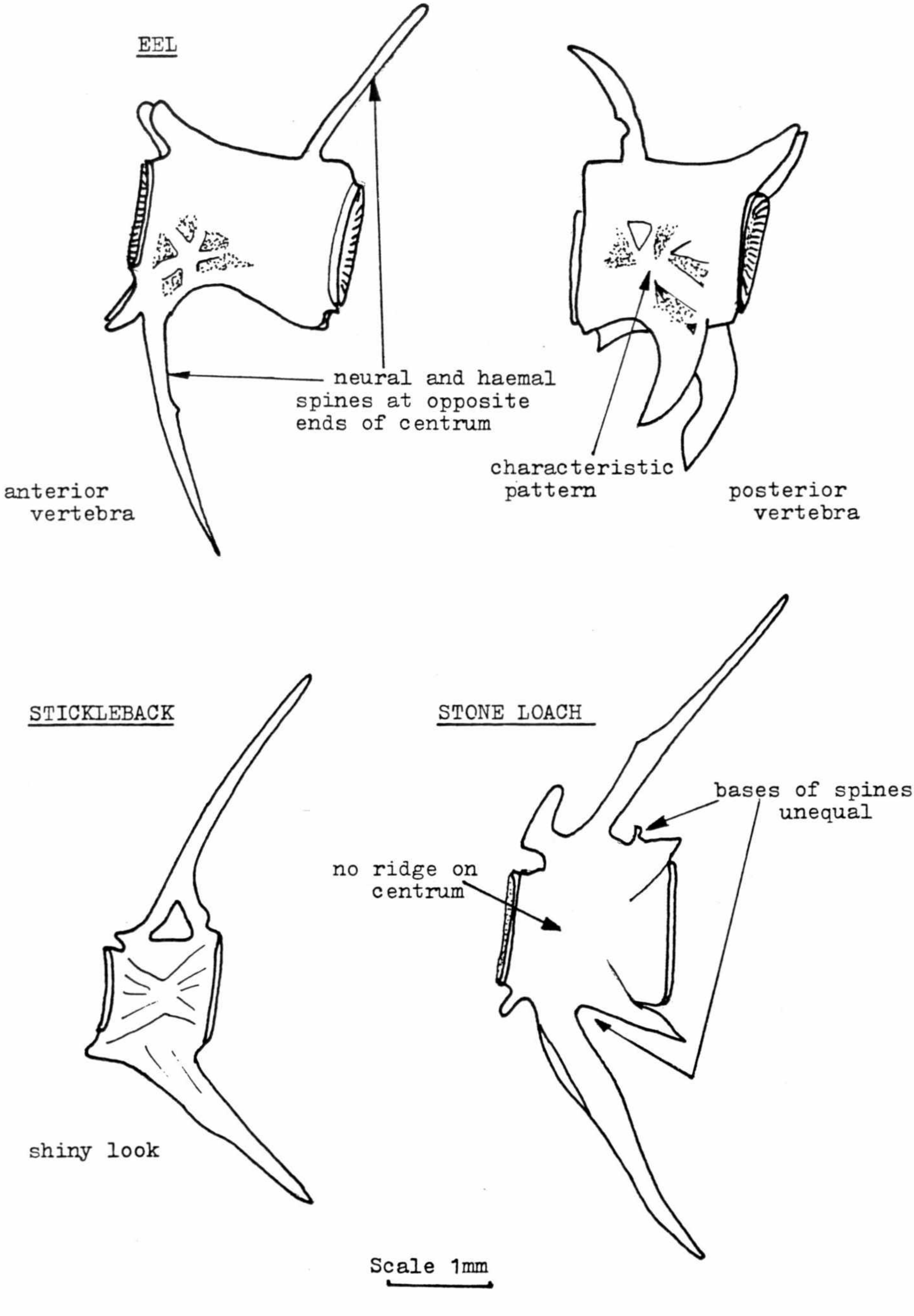
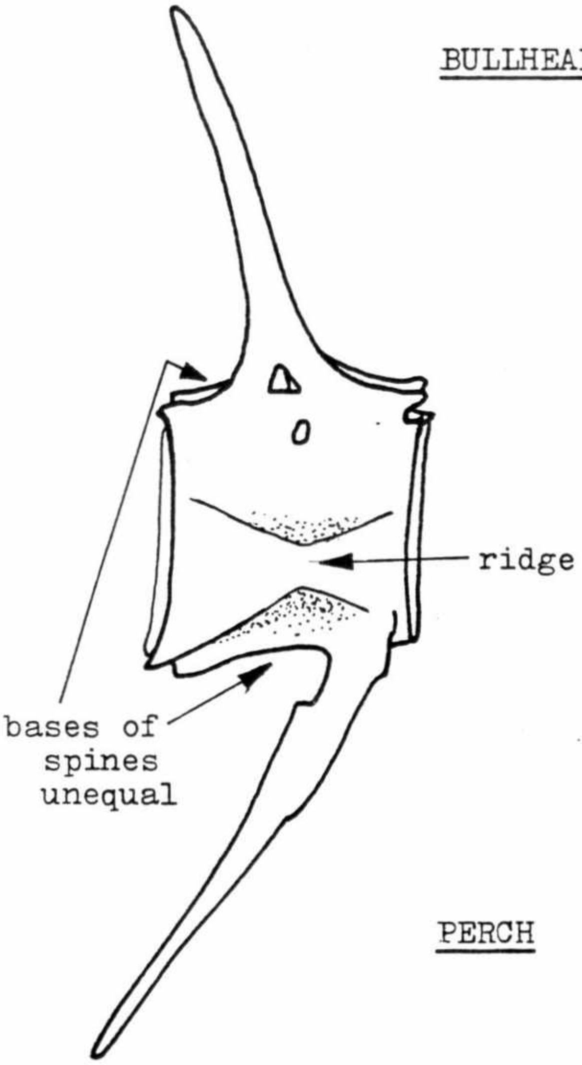
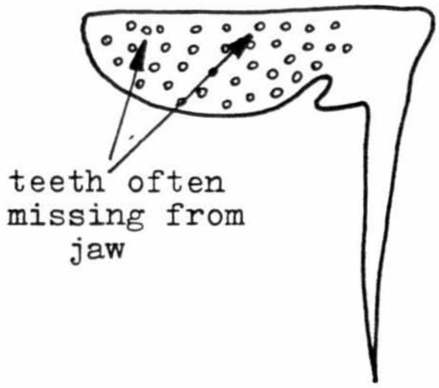

EEL
neural and haemal spines at opposite ends of centrum
characteristic pattern
anterior vertebra
posterior vertebra
STICKLEBACK
STONE LOACH
bases of spines unequal
no ridge on centrum
shiny look
Scale 1mm

Fig 7.(cont.)

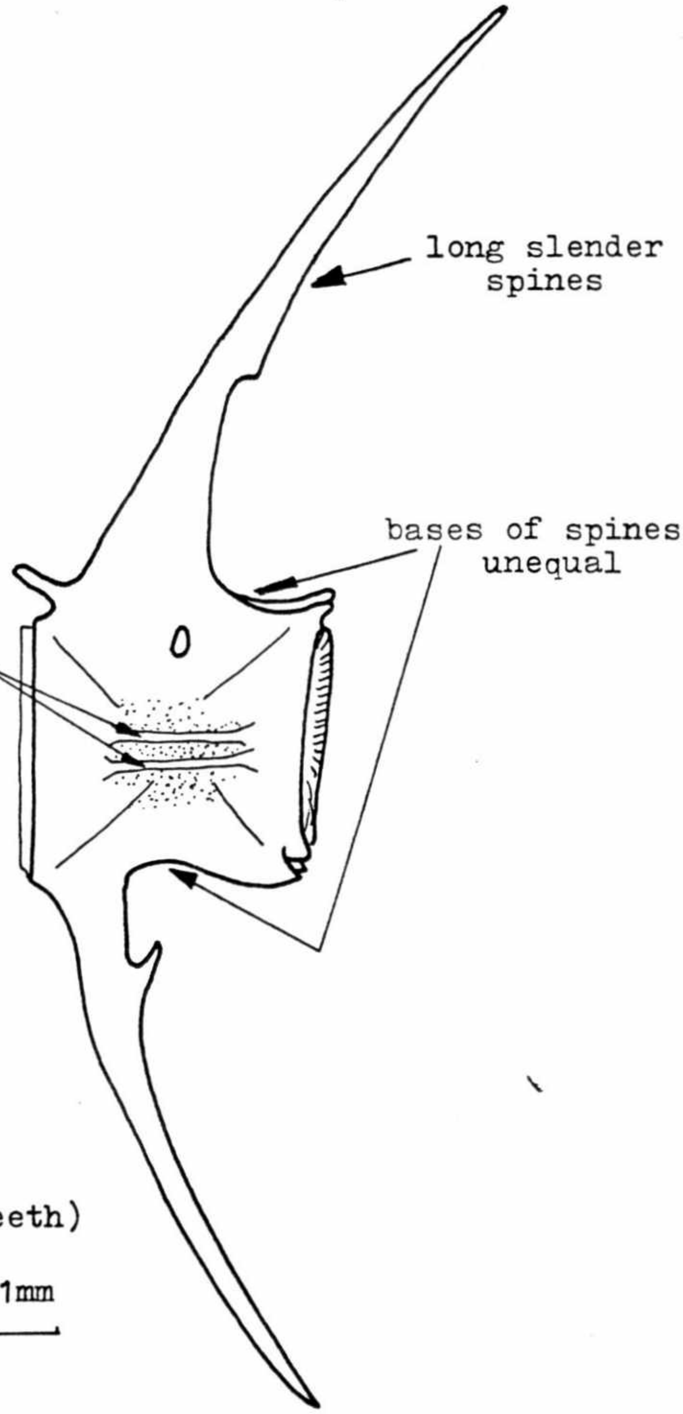
BULLHEAD



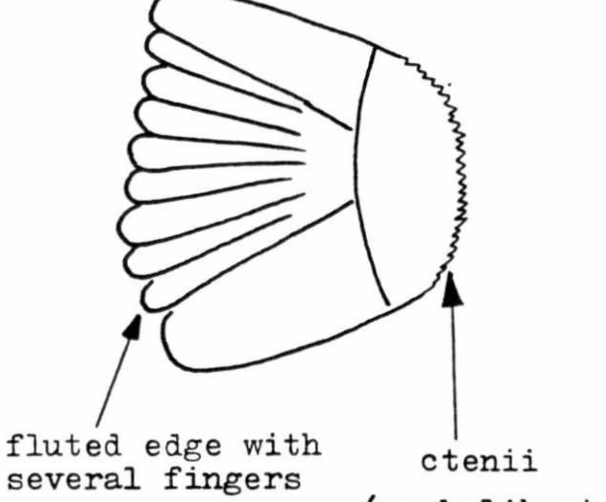
JAW



PERCH



SCALE



Scale 1mm

Fig 7.(cont.)

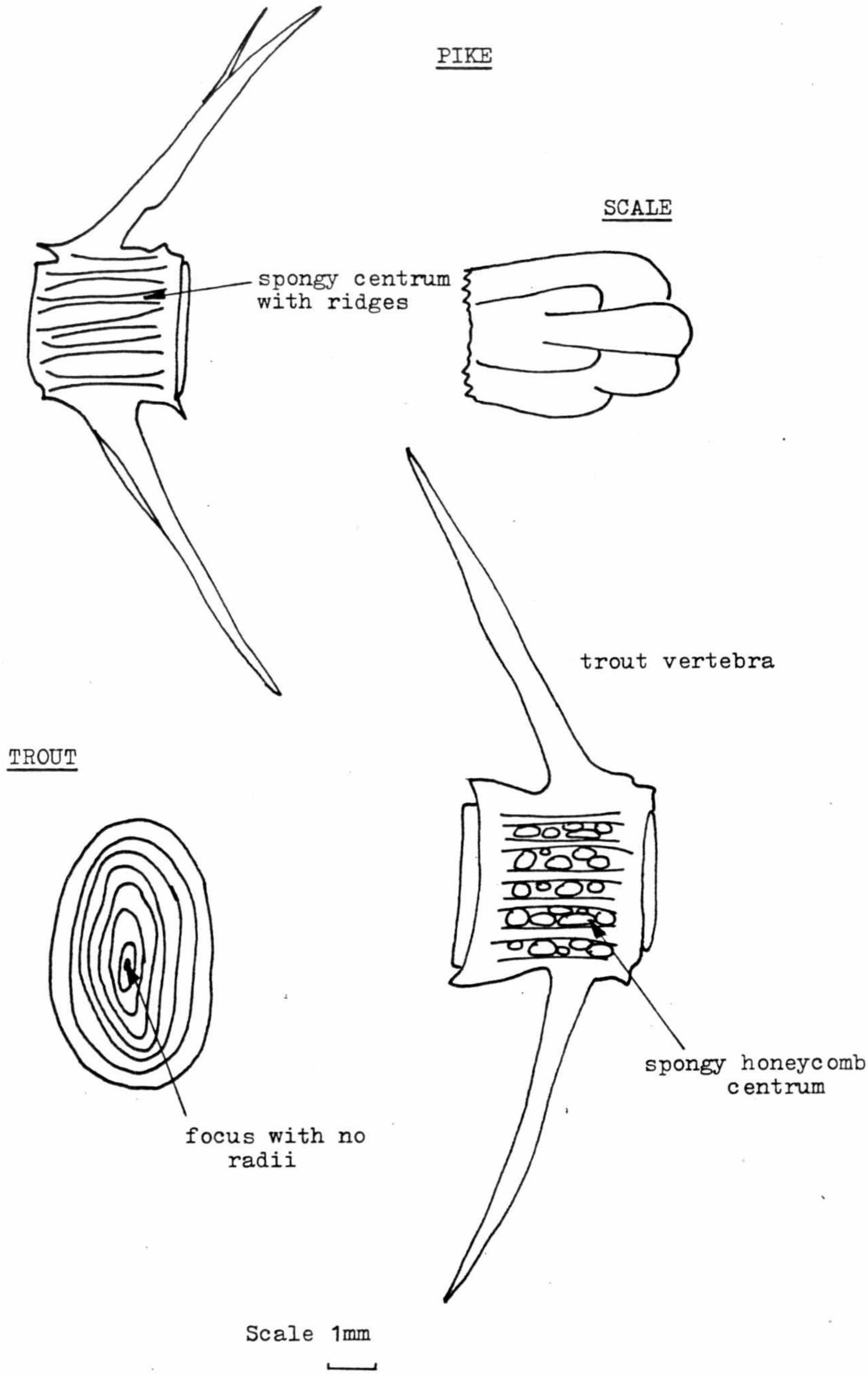

PIKE
SCALE
spongy centrum with ridges
trout vertebra
TROUT
spongy honeycomb centrum
focus with no radii
Scale 1mm

Fig 8. Graphs showing the fish length/vertebral size(caudal) correlation calculated by Wise(1978).

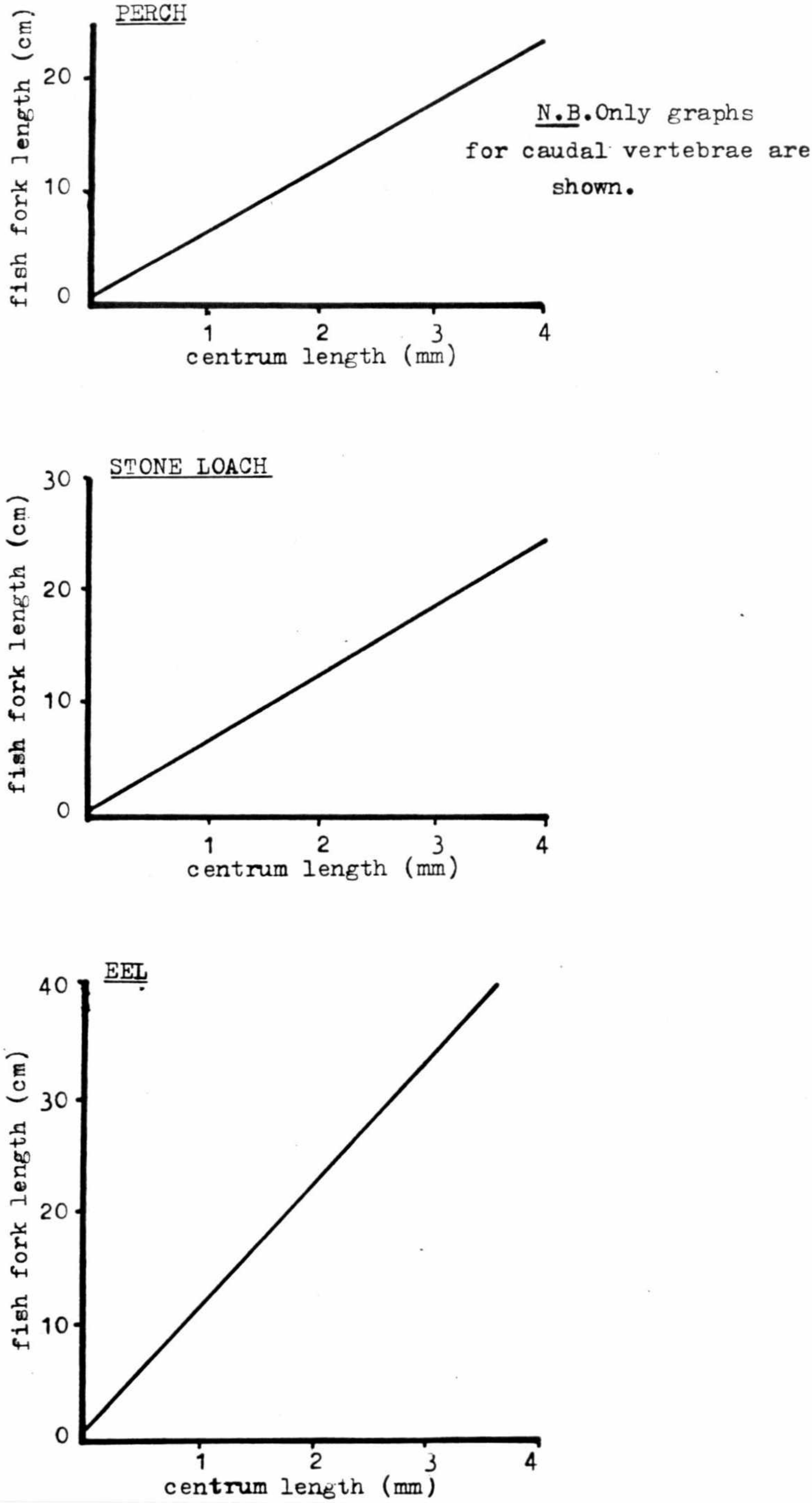
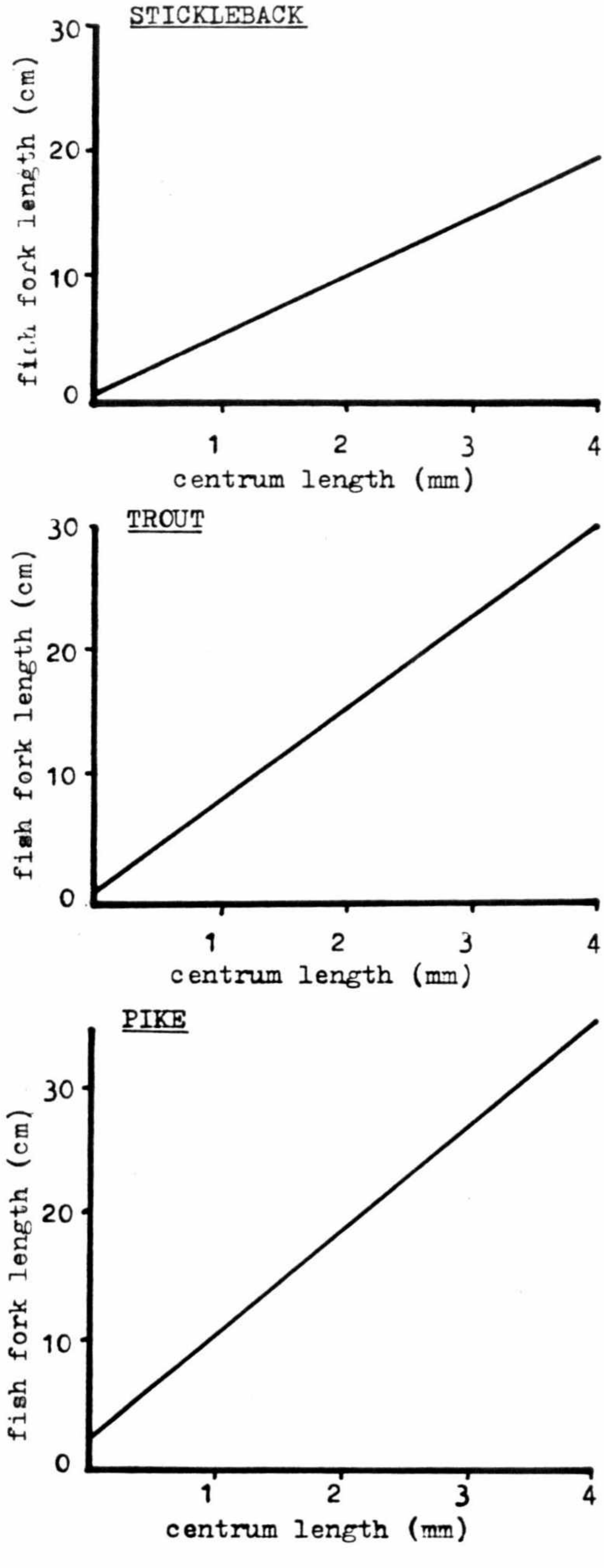


Fig 8. CONTINUED.



not characteristic of the vertebral column as a whole. Anterior vertebrae can be distinguished by the large transverse precesses, whereas the posterior caudal (tail) vertebrae have the transverse processes joined to form one ventral haemal spine (Fig.7).

This method of estimating fish size is based upon the premise that vertebral length is positively correlated with the length of the fish. Wise (1980) studied the fish length/vertebral size correlation of eight species of fish (Fig.8). The data from these analyses was used for calculation of fish length in the present study.

The vertebrae of each fish species was measured using a calibrated eyepiece, in preference to using calipers on the small fragile specimens. Measurements were taken to an accuracy of 0.1mm. The data given by Wise (1980) was tested against the vertebrae from the reference collection where the fish were of known length. The results gave an accuracy of within 5%. The majority of measurements were made on posterior (caudal) vertebrae. Damaged vertebrae were not included in this analysis since it was not possible to determine from what position on the vertebral column they originated. Vertebrae which were not clearly identifiable were also rejected. The mean centrum length was calculated for all vertebrae of each fish species present in a spraint. In some cases distinct size differences were observed, indicating more than one of the same species being present. This was often verified by the presence of more than one jawbone or operculum in the spraint. Minnow, chubb, gudgeon, and roach were classed as Cyprinidae, as the vertebrae are indistinguishable without the additional presence of scales or pharyngeal teeth, all other fish were identified to species level.

3.3.2 AMPHIBIA.

Amphibia were identified primarily by the presence of the long bones and vertebrae (Webb 1977), and these were compared with a specimen of frog (Rana temporaria) in the reference collection. In spraints the bones from frogs and toads were frequently indistinguishable and were therefore only grouped as 'amphibia'. The bones of amphibians are characterized by their hollow form, compared to bones from birds with their supporting trabeculae, and mammal bones, which appear almost solid.

3.3.3 BIRDS.

The occurrence of feathers in the spraints was somewhat of a rarity, but when present were identified using a key (Day 1966) to downy barbules. In many cases it was very difficult to accurately identify to genera since the part of the feather required was absent.

3.3.4 MAMMALS.

The majority of hair samples found in spraints were identified as otter. The presence of prey hair was accompanied by mammal bones. The hairs were identified using a key (Day 1966), but again, like the feathers, the absence of guard hairs used for identification made classification of the mammal difficult.

3.3.5 INVERTEBRATES.

The major crustacean found was crayfish (Astacus fluviatilis) which is easily distinguishable by the presence of the exoskeleton in spraints. When crayfish are taken in quantity, the spraints appeared bright orange in colour. No estimation could be made on the number of crayfish eaten since the exoskeleton was broken into small pieces. Whole freshwater shrimps (Gamarus sp.)were also occasionally present, however, because of their small size it was not known whether these were taken by the otter or by the fish prey. The latter applied to many of the freshwater invertebrates which were identified using the key by Quigley (1977). Terrestrial beetles (Carabid sp.)were also found to occur, but these are unlikely to be of major dietary importance.

3.4 METHODS OF DATA ANALYSIS.

Most studies of diet selection aim to present the results as the realtive proportion of the differnt types of prey taken. Three methods of presemtation are in common usage; frequency of occurrence, bulk estimation, and relative estimated bulk.

(1) Frequency of occurrence.

The occurrence of a particular prey in a spraint was scored as present, and then summated for the total number of spraints containing that item, for each site and watershed. The proportion is expressed as a percentage of the total number of spraints, thus:-

$$\text{Frequency of occurrence(\%)} = \frac{\text{Number of times prey A occurred}}{\text{Total occurrence of all prey}} \times \frac{100}{1}$$

(2) Relative estimated bulk.

For each spraint the bulk of identifiable prey remains were estimated. Using a scoring system devised by Wise (1978). The bulk of a particular prey type was scored on an arbitrary scale from 1 - 10. A bulk estimate of 1 indicated that the prey type was present only as a trace,this then graded upward to 10, indicating that the spraint was made up entirely of one prey type. It was also taken into account that the unidentifiable remains of e.g., fish spines, were probably from the same animal. The score for each prey type was then summated and its proportion of the total number of spraints calculated. The number of spraints analysed was multiplied by 10 which would be the maximum score for each spraint.

$$\text{Relative estimated bulk(\%)} = \frac{\text{Sum score prey A}}{\text{Total number of spraints x 10}} \times \frac{100}{1}$$

(3) Bulk estimates.

The bulk proportion of each prey type calculated for method (2) were multiplied by each individual dry spraint weight. This figure was then divided by the sum of all the prey types, multiplied by total weight of the spraints.

$$\text{Bulk estimate(\%)} = \frac{\text{Score of prey A x dry weight of spraint containing score of prey A}}{\text{Sum score all prey types x total spraint weight}} \times \frac{100}{1}$$

The conversion factors calculated by Wise (1978) were applied to the bulk estimate and their importance assessed.

CHAPTER 4

RESULTS.

4.1 FREQUENCY OF SPRAINTING SITES.

Analysis of the use of substrates as sprainting sites showed that on the North Tyne, 92.1% of spraints were deposited on stones, 7% on logs and 0.9% on sand or vegeation. On the Blyth watershed all the spraints were found on stones, and on the Wansbeck-Font, 98% were on stones and 2% on the ground,

4.2 HABITAT TYPE.

Analysis of the habitat type around the sprainting areas is given in Table 3. The figures for the North Tyne relate to the amount of cover in the habitat as a whole, since much of the North Tyne habitat is open, the otters have no alternative for sprainting sites, whereas on the Blyth, which was considered as a fairly enclosed habitat, spraints were found in mainly open places, the possible reasons for which will be discussed later. The otter appears to use cover much more on the Wansbeck-Font watershed and there is a reduction in the use of hovers as sprainting sites.

4.3 PREY DIVERSITY AND FREQUENCY.

The major prey groups taken by the otter are shown in Fig.9, fish were the principal dietary consituent on all three rivers (North Tyne, 88.6%; Blyth, 96.2%; Wansbeck-Font, 83%). Amphibians were the seocnd most important prey item on the North Tyne, whereas crayfish and crayfish/amphibia were of secondary importance on the Blyth and Wansbeck-Font respectively. Mammal and bird were occasionally taken on the North Tyne, although these dietary items were never found in spraints from the river Blyth. On the rivers Wansbeck and Font, bird prey was an infrequent item in the diet.

Figure 10, gives the frequency of occurrence of prey items in the diet of the otter on the rivers studied. The North Tyne watershed shows the greatest variety of prey in the diet (Fig.10a), comparison of the

Table 3. THE FREQUENCY OF HABITAT TYPE AROUND SPRAINTING SITES ON THE THREE WATERSHEDS.

Habitat type	North Tyne	Blyth	Wansbeck-Font
OPEN	83.3%	61.2%	45.8%
COVER	4.4%	12.5%	33.3%
HOVER	12.4%	17.5%	1.7%
UNDER BRIDGE	-	8.7%	15.0%
UNDER TREE	-	-	4.2%

Table 4. COMPARISON OF THE NUMBERS OF ALL PREY ITEMS FROM THE OTTERS DIET DURING SPRING AND SUMMER

prey items on all rivers	SPRING (Mar,Apr,May)	SUMMER (June)
eel	58	12
perch	15	0
stone loach	41	4
bullhead	45	1
Thymallidae	0	1
salmonid	41	1
Cyprinidae	25	2
stickleback	10	2
pike	4	0
crayfish	21	0
amphibian	12	0
moorhen	1	1
Apodemus	0	1

Fig 9. THE PROPORTIONS OF THE PREY GROUPS IN THE DIET OF OTTERS ON THE THREE WATERSHEDS.

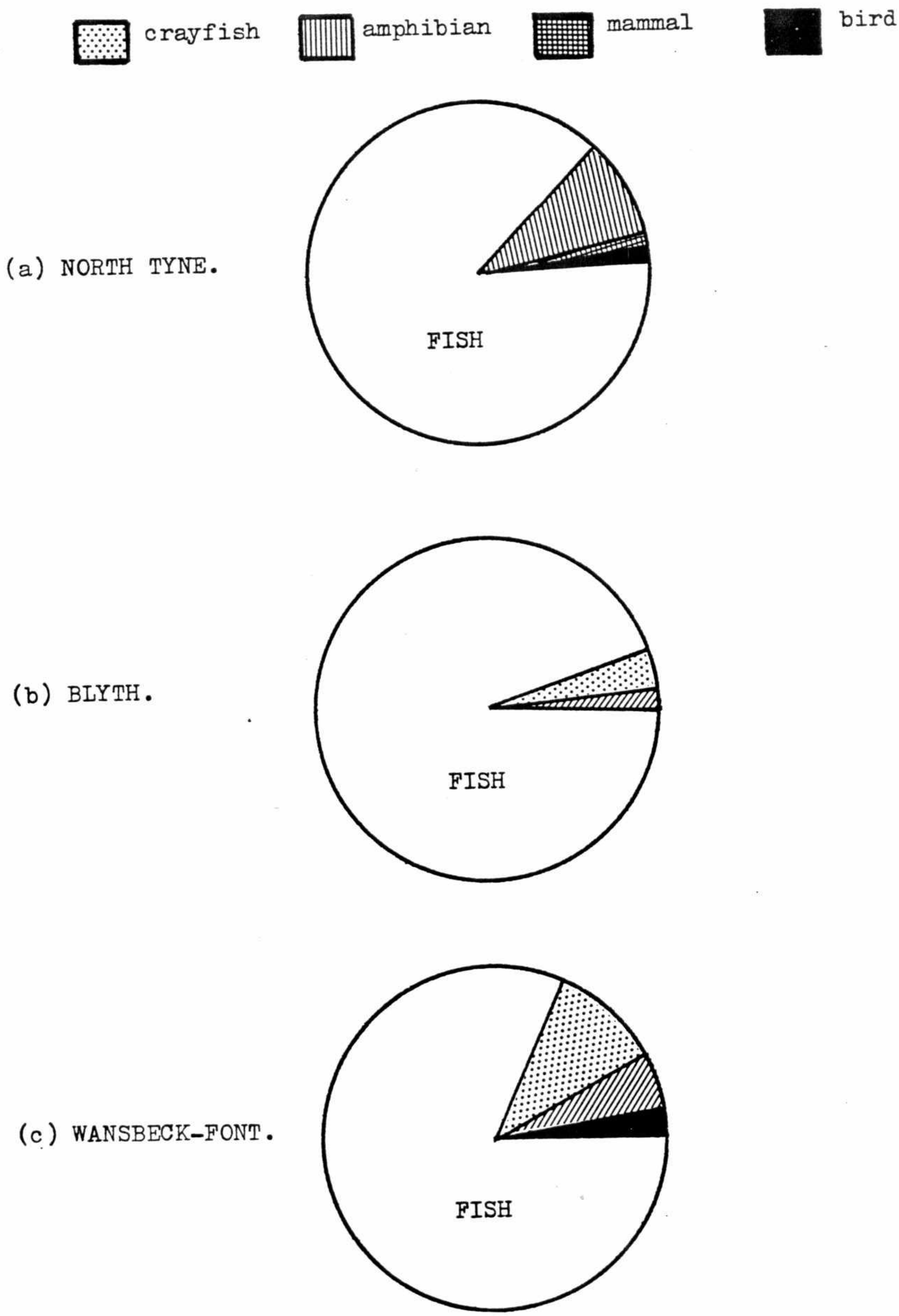
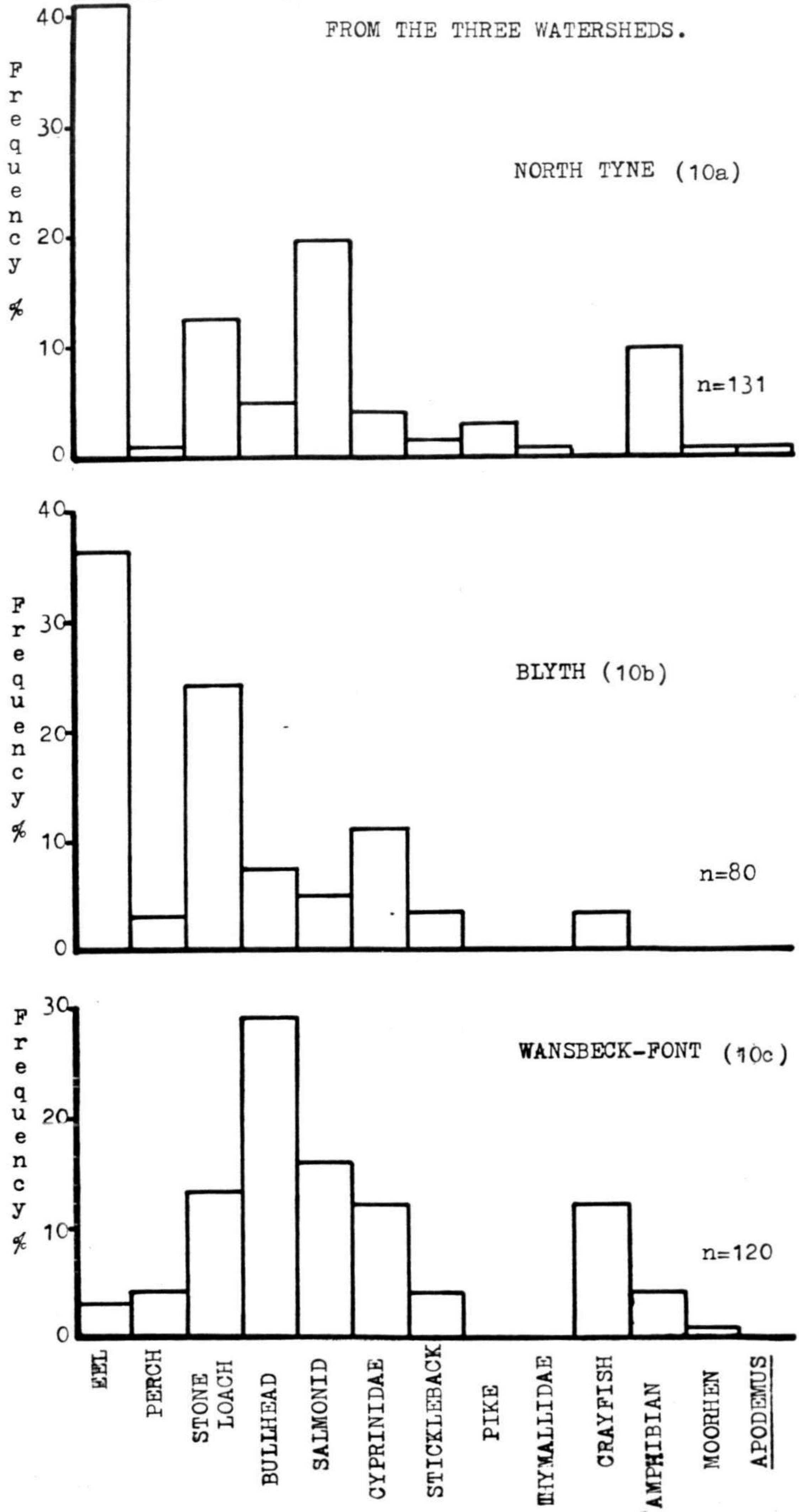


Fig 10. FREQUENCY OF OCCURRENCE OF THE PREY TYPES IN SPRAINTS FROM THE THREE WATERSHEDS.



frequency of occurrence of the major prey species (Fig. 10a), showed that on the North Tyne eel occurred more commonly in the diet than did other prey species, ($\chi^2 = 11.41$, $p < 0.001$), and on the Wansbeck-Font watershed, bullhead were present in significantly higher numbers in the diet than were other prey type ($\chi^2 = 5.49$ $p < 0.05$). On the Blyth there was no significant difference between the occurrence of the major prey species.

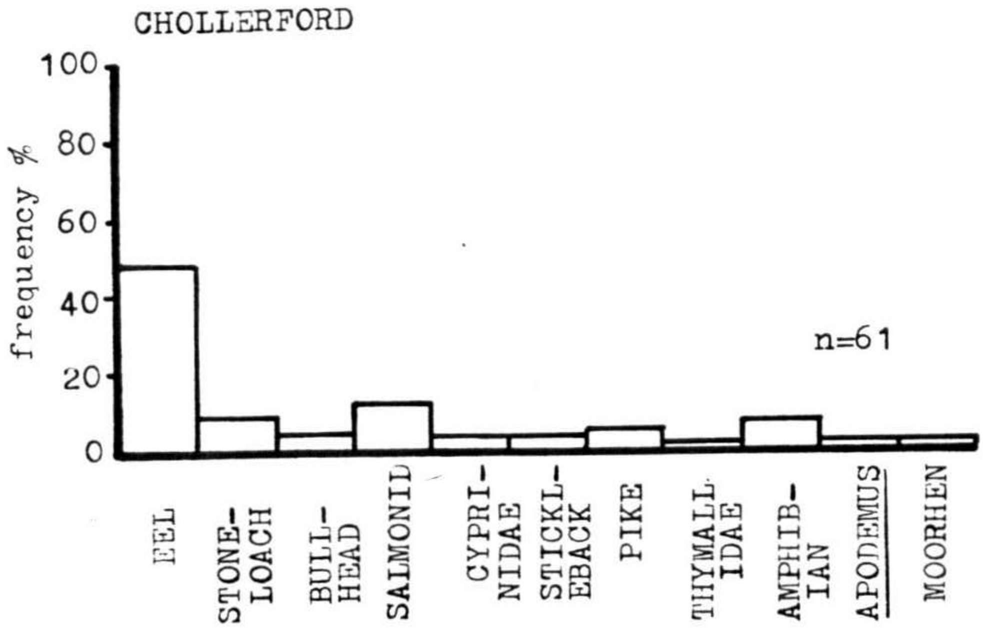
On the North Tyne (Fig.10a) salmonids, probably trout, stone loach, bullhead, pike, Cyprinidae, stickleback and Thymallidae from the other fish prey species. The only occurrence of bird on this watershed was moorhen, (Gallinula chloropus) and the only incidence of mammal found in the present study, was a single occurrence of wood mouse (Apodemus sylvaticus). There was a notable absence of crayfish in the spraints.

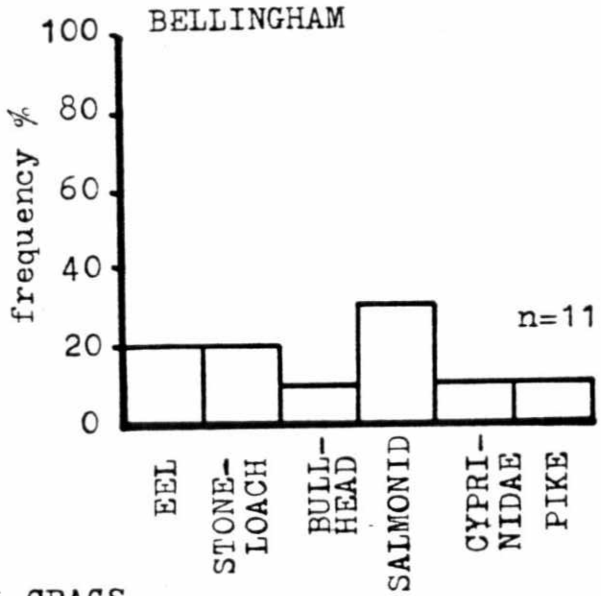
The frequency of occurrence of prey in spraints collected from the river Blyth (Fig.9b), shows a diet consisting almost entirely of fish (96.2%), with crayfish occurring only in small amounts. Eel again, occurs most frequently in spraints (36.7%, see Fig.10b) followed by stone loach, Cyprinidae, bullhead, stickleback, salmonid and perch. No bird, mammal or amphibian remains were identified in spraints from the Blyth.

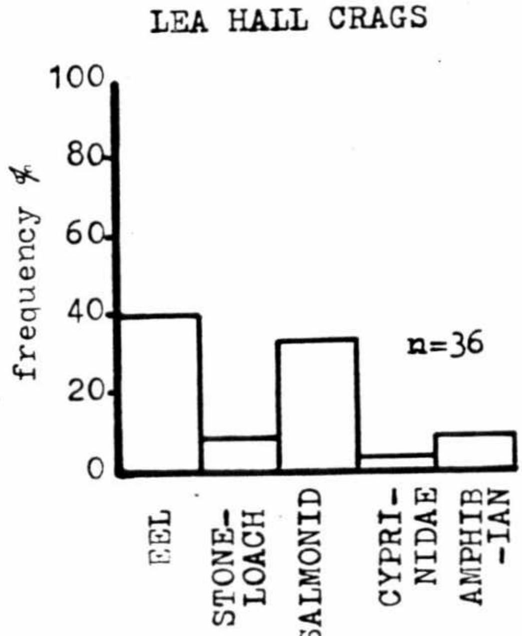
On the Wansbeck-Font bullhead forms the major prey taken. Salmonid, stone loach, crayfish and Cyprinidae also appear to be of importance. In contrast to the other study areas, the occurrence of eel is very low, only 3.4%. Perch, stickleback and amphibian were also identified, with one occurrence of bird, moorhen. There was an absence of pike in the diet from the Wansbeck-Font and Blyth watersheds.

Figure 11 shows the frequency of occurrence of prey items at the various sites on the North Tyne watershed. Greenhaugh, Benthouse Bridge, Hawksley Burn and Errington Burn have been omitted as the number of spraints collected was less than five at each site.

Eel forms the major prey from Chollerford and Lea Hall Crag sites, Fig 11. FREQUENCY OF OCCURRENCE OF PREY ITEMS IN SPRAINTS FROM THE NORTH TYNE SITES.







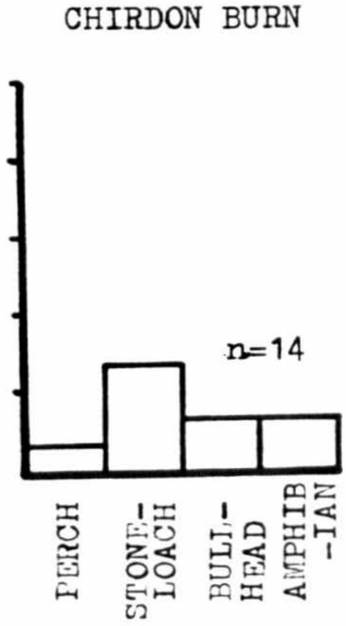
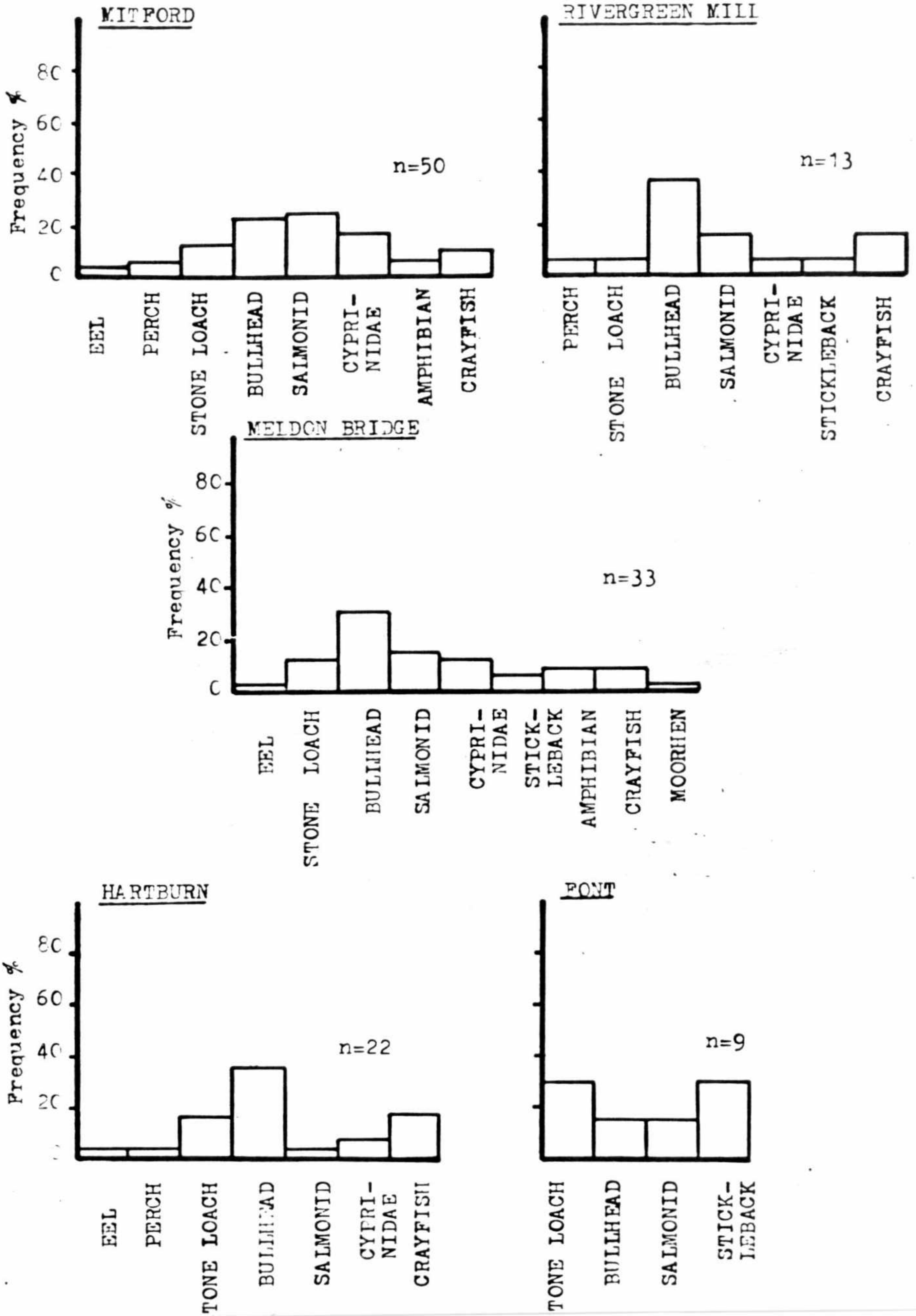


Fig 12. FREQUENCY OF PREY ITEMS IN SPRAINTS FROM THE WANSBECK-FONT SITES.



whilst trout, stone loach and Cyprinidae are more common at the other sites studied.

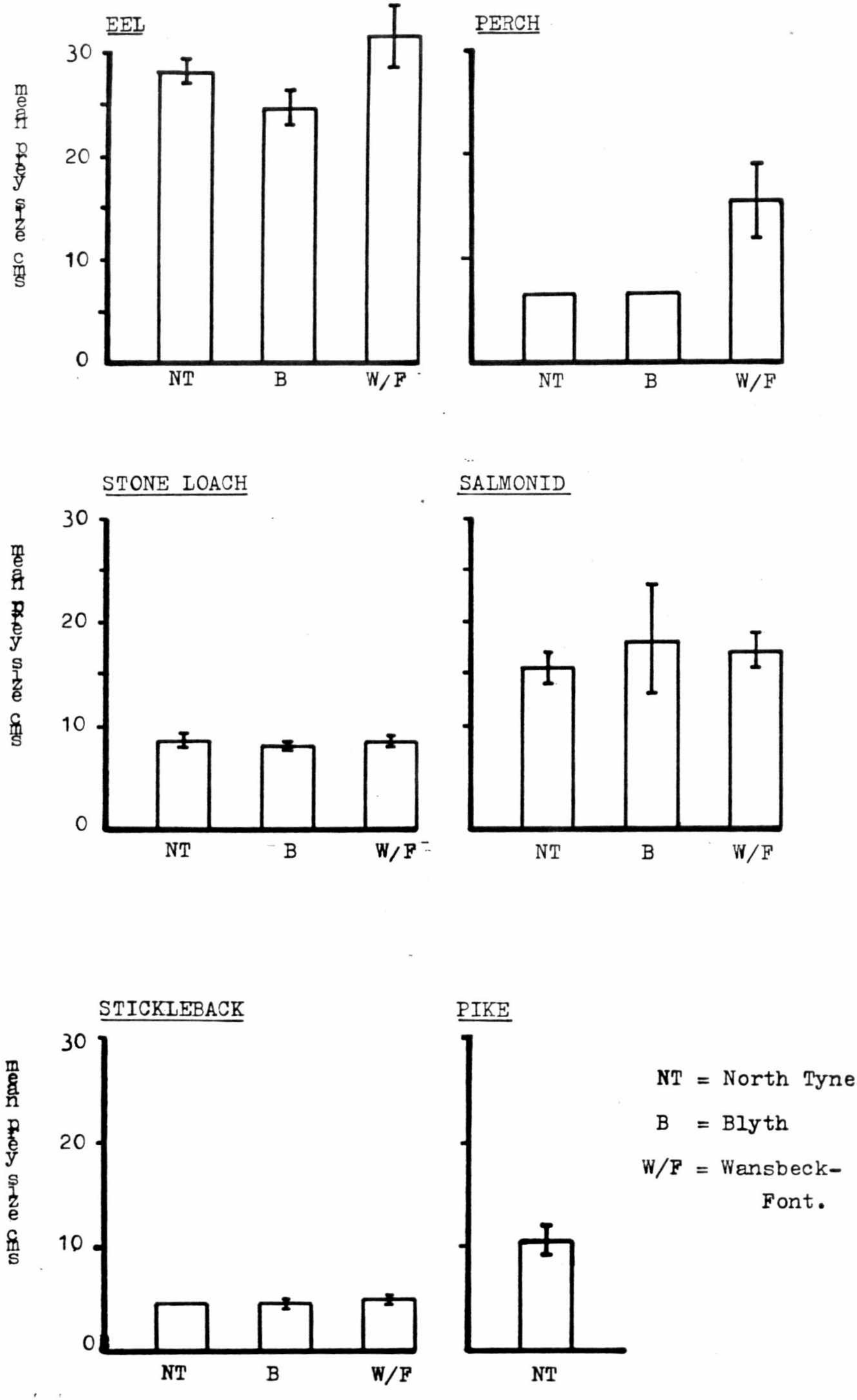
The frequency of items on the Wansbeck-Font watershed is given in Fig.12. Bullhead, trout and stone loach form the majority of the prey taken at the sites on the Wansbeck, whereas stickleback and stone loach appear frequently in the spraints taken from the Font site.

Comparison of fish component in the diet on the three rivers showed that significantly more eel were taken on the North Tyne than on the Wansbeck-Font ($\chi^2 = 48.6$, $p < 0.001$) and more on the Blyth than the Wansbeck- Font ($\chi^2 = 37.3$, $p < 0.001$). Salmonids were taken more frequently on the North Tyne ($\chi^2 = 8.3$, $p < 0.01$) and Wansbeck-Font ($\chi^2 = 13.4$, $p < 0.001$) than the Blyth. A greater number of bullhead were taken on the Wansbeck-Font than on either the Blyth ($\chi^2 = 13.4$, $p < 0.001$) or on the North Tyne ($\chi^2 = 25.5$, $p < 0.001$). Stone loach were taken more frequently on the Blyth ($\chi^2 = 4.0$, $p < 0.05$) and Wansbeck-Font ($\chi^2 = 5.2$, $p < 0.05$) compared with the numbers obtained from the North Tyne watershed. The Blyth and Wansbeck-Font also showed significantly higher frequences of Cyprinidae in the diet than on the North Tyne ($\chi^2 = 4.0$, $p < 0.05$ and $\chi^2 = 5.2$, $p < 0.05$ respectively). Crayfish were found to be taken in greater numbers on the Wansbeck-Font watershed than on the Blyth ($\chi^2 = 3.9$, $p < 0.05$). The raw data used for these analyses is given in Appendix 1. All other statistical analyses indicated that the remaining fish species were taken in approximately the same frequency on each of the watersheds.

4.4 PREY SIZE.

Analysis of the size of the prey taken by otters was only possible on the fish component of the diet. Only those prey identified to species level and for which regression analysis allowed calculations of fish size, could be used in this analysis, (Fig.13). The longest fish taken were eel, (mean size 31cm) on the Wansbeck-Font watershed (the larger

Fig 13. THE MEAN SIZE OF PREY TAKEN ON THE THREE WATERSHEDS.



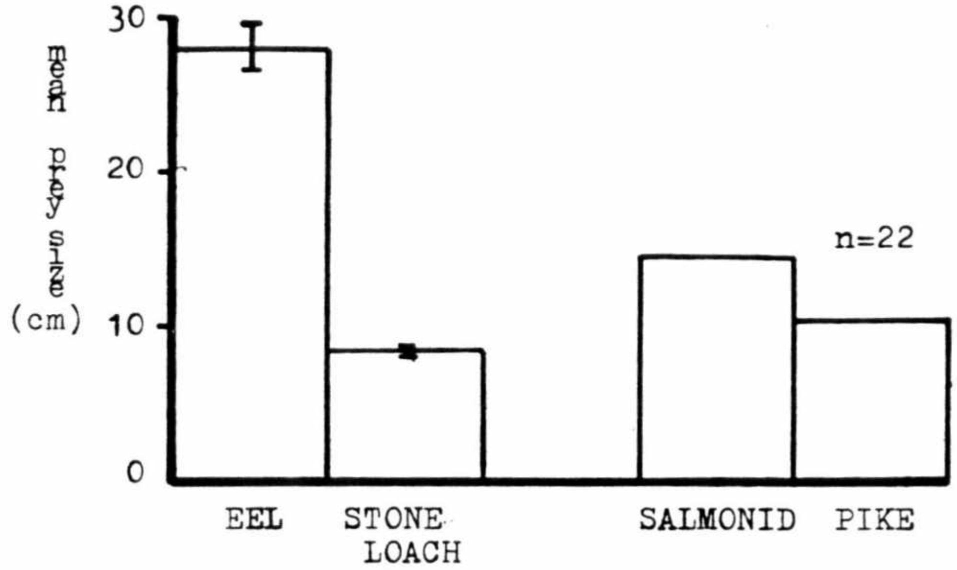
fish species e.g., eel and salmonid having a greater standard error because of the variation in the large sizes taken). The problem arises in comparing fish of similar length but of different species. An eel which is the same length as a trout will have much less flesh and will form a smaller proportion of ingested material than the bulky trout, therefore comparison of intake cannot be made on the basis of fish length between different species. The small species, which include stone loach and stickleback, were virtually all fully grown mature fish, whereas the range of eel in the otters diet varied from mature specimens to minute elvers a few centimetres long. The stone loach taken also appeared to be larger on the Wansbeck-Font watershed, whilst the salmonids taken were larger on the Blyth. Students t - tests were applied to the prey size data and showed that significantly larger eel were taken on the Wansbeck-Font compared to the Blyth, ($t = 2.65, p < 0.05$ d.f. = 29). Similarly the size of perch taken on the Wansbeck-Font tended to be larger than on the Blyth. However, the data on eel is the only result of value, since the sample size for perch was small (5). The size of perch taken on the North Tyne tended to be smaller than on the Wansbeck-Font, although again the sample size was less than five. It was not possible to back-calculate the size of bullhead taken by the otter, although most vertebrae found in spraints were of a similar size to those in the reference collection, taken from 8cm long fish. Chubb, roach, minnow and dace could not be distinguished from each other and were therefore all classified as Cyprinidae.

4.5 SEASONAL VARIATION IN PREY DIVERSITY AND SIZE.

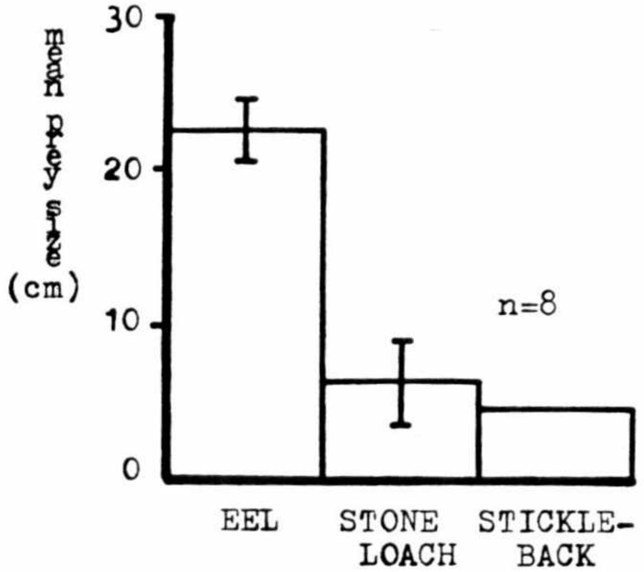
Only the results from the North Tyne could be used to provide evidence of seasonal variation in prey size over the study period, since no spraints were collected from the Blyth and Wansbeck-Font in June due to floods. The mean size was calculated for the months of March, April and May (Spring) and June (Summer). Eel and stone loach

Fig 14. MEAN SIZE OF PREY ON THE NORTH TYNE DURING SPRING AND SUMMER.

SPRING



SUMMER



were the only species occurring at both areas during spring and summer, (Fig.14) however there was no difference in the sizes taken at each season for either species.

An analysis was made of the seasonal occurrence of particular prey species for the three watersheds combined, the results are given in Table 4. As with the comparison of size, summer samples were too small for analysis, but results do appear to indicate less crayfish, amphibians, Cyprinidae, salmonids and perch in the diet for the summer period.

4.6 OTHER ITEMS IN THE DIET.

Invertebrates were present in a small proportion of the spraints examined, the majority were fresh water shrimp (Gammarus sp.) and beetles (Coleoptera). Other species identified were snails (Lymnaeidea) damsel fly and nymph.

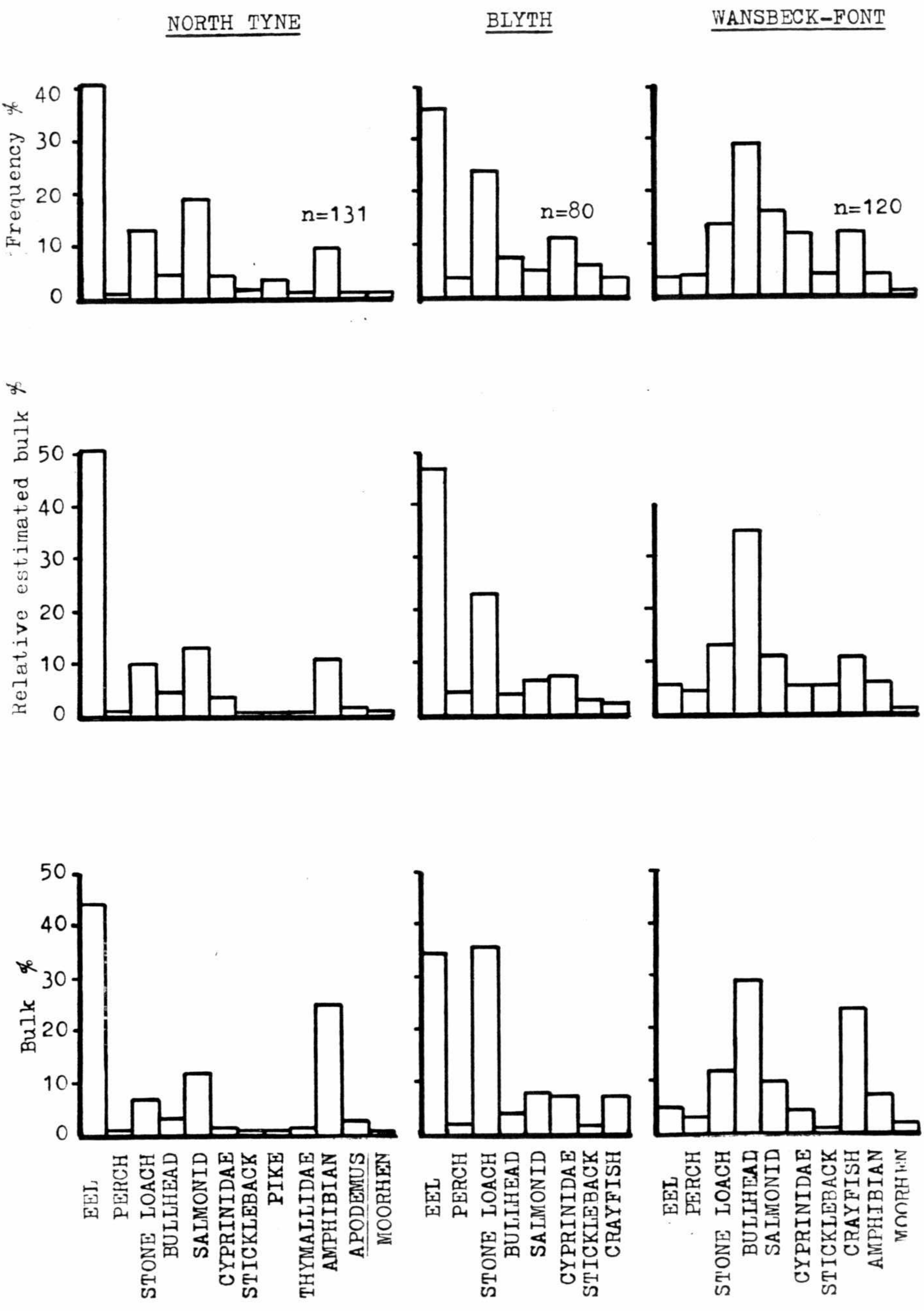
4.7 ANALYSIS OF THE DATA USING THE THREE METHODS.

In addition to analysing the results in this study using frequency of occurrence, the methods of relative estimated bulk and bulk analysis were also employed. For the purposes of comparison the data given previously in Fig.10, is represented again in Fig.15 along with the analysis of relative estimated bulk and bulk analysis for the three study areas.

The relative estimated bulk takes into account the volume of prey items contained in a spraint and results using this method on the North Tyne data showed an increased proportion of eel, the major prey item, and a concomitant decrease in the majority of other items, indicating that eel was under-estimated in its importance in dietary intake using frequency of occurrence. Eel, bullhead and Cyprinidae were under-estimated on the Blyth watershed, whilst on the Wansbeck-Font area, bullhead and Cyprinidae were also taken in greater proportions using this method.

The application of the bulk method of analysis whuch takes into account the weight of prey remains, gave results between those of frequency

Fig. 15. HISTOGRAMS ILLUSTRATING THE THREE METHODS OF DATA PRESENTATION.



and relative estimated bulk. Bulk analysis showed an over-estimation of stone loach in the spraints from the North Tyne, whilst the presence of amphibians was greatly under-estimated. On the Blyth the proportion of stone loach taken was greater by bulk analysis than eel, which had been ranked of major importance, using frequency and relative estimated bulk analysis. Stickleback were over-represented on the Wansbeck-Font, that is, although they occurred frequently, the actual bulk of the spraint (and therefore diet) that they formed was very low. The bulk of crayfish is also higher than is indicated by frequency analysis, the reason for this will be discussed later.

Conversion factors were applied to the data from bulk analysis to calculate the original weight of prey ingested in grammes. The conversion factors used were those calculated by Wise (1978), results are shown in Table 5, and indicates the large weight of eel ingested compared to the other prey items, except on the Wansbeck-Font where bullhead formed the major prey. Amphibians on the North Tyne, which were shown to be under-estimated in frequency, formed a large proportion of the prey by weight intake. Salmonids (trout) were important prey by weight on all the rivers.

Table 5. THE APPLICATION OF CONVERSION FACTORS TO CALCULATE THE TOTAL WEIGHT OF PREY ITEMS INGESTED ON THE THREE WATERSHEDS.

Prey type	C.F.	weight of prey ingested.(g)		
		N.T.	B.	W/F.
eel	40	1784	1380.4	203.2
perch	16	7.52	33.92	54.8
pike	60	46.8	-	-
trout	20	239.2	158.6	214.0
stickleback	15	3.6	27.0	28.65
bullhead	15	55.85	59.55	439.5
bird	35	15.4	-	61.95
mammal	11	31.35	-	-
amphibian	17	424 .4	-	127.67

C.F. = conversion factor.
N.T. = North Tyne
B. = Blyth
W/F. = Wansbeck-Font

CHAPTER 5.

DISCUSSION.

The results obtained in this study reinforce the conclusions of previous research into the diet of the otter, that is, the otter primarily eats fish, and that bird, mammal, amphibia and crustacea are important where there is a local or seasonal abundance.

At the start of the sampling programme, there was some concern expressed as to whether the removal of spraints would disturb the otters, since they do serve a function as social signals. However, it has previously been found (Erlinge, 1969; Watson, pers.comm., and Wise, 1978) that removal of spraints does not affect sprainting activity and that the scent which remains is sufficient for the animal to relocate the site. In any case, under normal conditions, spraints would be removed by rainfall and flooding of the river, and this appears to have no effect on the animals. The only exception to spraint collection was made in the case of spraints found in the holt entrance on the river Blyth, where otters were known to reside and it was thought that disturbance of the holt should be kept to a minimum. Spraints collected at easy access points along a river may not be a representative sample of the spraints as a whole (O'Conner et al 1977) and there may be a bias on looking under bridges for spraints. It is very probable that large numbers of spraints were not collected due to problems of access and problems in finding them. Another possible source of error may arise from the mis-identification of prey items or from the processing of spraint samples. Small fish vertebrae may be completely digested by the animal and can therefore be missed in a spraint analysis. Small vertebrae, fine hairs, and the undigested remains of invertebrate prey e.g., worm chaetae may be washed through the sieve during the cleaning process. However, it is not thought that this represented a major source of error in the present study. Large vertebrae may not be totally consumed by the otter and therefore there would be an absence of the larger fish prey in the dietary analysis. In some cases large fish scales occurred in the spraints but the accompanying vertebrae were absent. Lampreys consist of a cartilagenous skeleton and may undergo almost complete digestion by the otter, therefore being underestimated or even omitted, even though at certain times of the year they are abundant in the study rivers. Fairley (1972) in his study of the diet of the otter in Ireland found that there were marked differences in the frequencies with which various prey items occurred in the stomach and intestines of the animal. Eel remained in the stomach for long periods giving errors in both volume of prey consumed and its importance in the diet. This arises because eel have a high fat content, which slows down the action of water soluble proteases.

Erlinge (1967b) and Wise (1978) have studied the diet of otters in relation to the abundance of its prey populations and found that the feeding habit of the animal was a result of the change in behaviour and abundance of the prey, i.e., availability. Wise (1978) found that the otter specialises on fish at all times of the year, but show seasonal variation in the species taken. When the fish populations decrease in summer the diet is diversified to include more mammal and bird. The decrease in fish availability does not necessarily reflect population changes but behaviour changes caused by increased water temperature, resulting in increased fish mobility and easier escape from predators. The present results from the North Tyne (see Fig. 10a) showed a wide variation in the species taken, the majority of prey consisting of fish and amphibians and occasional occurrences of mammal and bird. From the data available on prey populations, one would expect the otters main prey to be trout, since the river and its tributaries are heavily stocked for angling purposes, and water bailiffs encourage the destruction of the eel wherever possible, since they predate both trout eggs and fry. However, the data obtained shows almost twice as much eel in the diet as trout, therefore either the otter is selecting eel as prey, or predation of the eel is related to their availability in terms of behaviour and swimming ability. Although Ryder (1955) states that the otter captures fish in proportion to their abundance, it appears probable that the increased mobility during the summer months, of salmonids, which are characteristically fast moving fish, evade the otter and cause it to seek an alternative more easily captured prey. Sheldon and Toll (1964) also found little predation on salmonids despite their high population level and concluded that the factors affecting the availability of food to the otter includes abundance and agility of fish, the habits of the species, the time of day the otters hunt, water stratification in different seasons and the fishing method employed by the otter. Eel may be favoured because besides being easy to catch, the species lack the numerous scales and spines of the Salmonidae. Erlinge (1967b)states that in general the otter prefers to feed on easily available food, rather than to hunt a favourite food item, and shows temporary specialisation of prey items during periods of abundance. Other fish species taken in the North Tyne are probably taken in relation to their abundance and ability to escape. Amphibians were probably caught in large numbers during spawning and periods when the river level was very low. No gudgeon, flounder, dace, or lamprey were found in spraints, although they are known to be present in the rivers. This could be for several reasons, either the vertebrae were present and remained unidentified, or were not present in the spraint because the prey was too difficult to catch, or in such low numbers that it occurred very infrequently in spraints. There was also one occurrence of Thymallidae, probably grayling, (Thymallus thymallus)which is surprising since this species was not thought to be present in the North Tyne. It is likely that the population of the species is very low and the occurrence of this prey in the otters diet is very rare. The low occurrence of mammal and bird may indicate that the otter can obtain sufficient food from the river without hunting on land. The absence of crayfish in the diet is surprising since the numerous tributaries of the North Tyne would provide an ideal habitat for these cructacea. It may be that the otters are not hunting up the smaller tributaries where the crayfish were present. Data from the sites on the North Tyne shows that the occurrence of eel is mainly in spraints from the Chollerford area. Eel remains were rarely found in spraints from the tributaries, such as the Chirdon Burn, and this may reflect availability, if in fact the prey was caught where the spraints were produced. Since digestion may take several hours, an otter may produce spraints several kilometres from where the prey was caught.

On the Blyth watershed 96.2% of the occurrences of prey were fish (Fig.9b) with eel forming the major prey (Fig.10b). Stone loach and bullhead were also important prey items. Again the occurrence of a particular prey species is a function of abundance and availability. Trout and perch, which are fairly fast moving fish, are only taken in small numbers. Crayfish were present in the diet but are probably hunted further up the river where is is less polluted and provides a more suitable habitat. There was a noticeable absence of bird and mammal in the Blyth spraints, possibly because in the months over which the spraints were collected, fish were abundant enough to supply a sufficient dietary intake. Unfortunately, the sample size of spraints for the Blyth was very small, and the revisiting of otters to their sprainting sites was very low, possibly indicating the large distance of river used by the animal in hunting for food.

In contrast to the previous watersheds, the Wansbeck-Font showed the majority of prey taken to be bullhead (Fig.10c) trout and stone loach. The rivers of this watershed are very stony in places and would provide ideal habitat for loach and bullhead, so it is probable that these species are fairly abundant. The decrease in eel on this area most likely reflects its population numbers, with trout being taken as the alternative prey.

Crayfish appear frequently and there was one incidence of moorhen feathers in a spraint. The sites within the watershed reflect the overall pattern of prey items taken, except on the Font, (Fig. 12) where stickleback and stone loach form the major prey items in spraints, surprisingly there are no crayfish in spraints from this site. It may be that otters eat crayfish from the Font and produce spraints further downstream at the Mitford site, therefore causing errors in interpretation.

Analyses of prey sizes showed the largest fish taken were eel Of 31cm on the Wansbeck-Font area, which with perch were significantly larger than on the Blyth. This could be either because there are greater numbers of larger individuals on the Wansbeck-Font, or that the otters are selecting larger prey. However, in general, the size of prey predated by otters is fairly uniform for each prey species. Of the small fish species, stickleback, and bullhead, it appears to be mainly adult fish which are taken, although for an otter to take prey less than 5cm long, one could postulate that its prey must be very abundant and require little expenditure of energy in catching.

Erlinge (1967b) found the common size of prey to be between 10 - 15cm while Greer (1955) frequently found otters to take trout of 35cm in length. Other research has shown varying prey sizes; eel;20 - 30cm in length (Webb 1975) and 22 - 42cm (Jenkins et al, 1979), bullhead, 15cm; pike, 25cm; minnow, 3.5 - 12.5cm; and trout only 11cm in length (Ostenson 1942). Therefore the composition and size of prey in the diet depends on what is available in the food environment. The actual length of prey bears little relation to the proportion of flesh ingested. Results obtained from the present study demonstrate that the food habits of the otter show local variation as well as variations between the major watersheds, and to a great extent the food environment determines the choice of prey to the otter.

It was hoped to include in this study some information about seasonal variations in the otters feeding habits on the three watersheds, but unfortunately the lack of summer samples allows only tentative conclusions to be made. A comparison of seasonal results from the North Tyne showed slightly larger eel and stone loach taken during the spring, and comparisons of the prey from all the watersheds (Table 4) indicates less crayfish, amphibians, Cyprinidae, trout and perch in the summer diet. Weir and Bannister (1973) found in Norfolk a decrease in Cyprinidae in summer and early autumn, when more crayfish were taken. The present study supports the results of decrease in Cyprinidae, but the increase in crayfish in the diet is not apparent, this could possibly be due to low local populations. Stephens (1957) found frogs to decrease as prey in July, which was also found in the present study, Jenkins et al (1979) showed that eel predominates in the diet except around mid-winter and after mid-summer. Perch were abundant in February and March, whilst the incidence of bird was largest in winter and in July.

Many authors have shown that various prey types in different areas form the major food in the otters diet. Hewson's (1973) study in Scotland showed the diet to contain a large percentage of mammal and bird, which is in direct contrast to the results found in the present study. Stickleback formed the majority of spraints by bulk (55%) followed by eel (25%) in results from otter diet analysis in Norfolk (Weir and Bannister 1973). Salmonids were found by Wise (1978) to form 59% of the bulk of spraints, eel formed the second most commonly predated species. Erlinge (1967b) study showed roach, perch, and bream to be the common prey, with larger specimens being taken in the summer. Not all research has indicated seasonal variation in prey (Fairley 1972) and it is possible that in the present study, if spraints were collected over the winter period, that prey differences in the diet may not be significant.

The incidence of vegetation in the spraints was very low but in some studies (Sheldon 1964) the proportion in terms of dietary intake may be significant. Sheldon also found that the otters purposely ate blueberries, which formed 1% of the diet.

The method used for analysing the results can very much over emphasise certain aspects. The use of frequency of occurrence has the disadvantage of over-estimating trace items and under-estimating those items which form the majority of the spraint. However, this simple method has been widely used and is generally thought to give an indication of the prey species present. The use of relative estimated bulk analysis takes into consideration both the prey species and the volume which the remains form in the spraint. This method, although more accurate than frequency does not take into account the weight of the prey items. Bulk analysis uses the comparison of weight of remains to indicate the proportions of the prey item in the diet. Both the methods using bulk require a subjective score for each prey item which may indicate a source of error. This was overcome to some extent by repeating the scoring procedure after some period of time had elapsed. Results were fairly consistent in estimation of the proportion of prey items formed in the spraint. On the whole, bulk analysis did show that frequency of occurrence under-estimated the importance of major items like eel, whilst minor items, like stickleback and perch were over-emphasised. However, it is impossible to say which method is more suitable since one does not know the actual quantities the otter is consuming. One eel may be eaten, but its vertebrae may occur in several spraints, so, using frequency of occurrence, the presence of the eel will occur as a major item. The use of bulk analysis allows the application of conversion factors, which indicates the weight of prey originally ingested, and takes into account the variation in prey volume formed by bone, fur, and feather.

On the North Tyne, amphibians appear only of minor importance by frequency, but the actual amount ingested was a quarter that of eel, the major item (see Table 5).

With the exception of crayfish, the presence of invertebrates in the spraints was probably accidental, either being consumed with the prey, or was part of the diet of the otters prey.

Since the exact origin is unknown, invertebrates cannot be included as items of importance in the diet. The incidence of perch vertebrae may also be higher than it should normally be, since adult perch may predate smaller perch, therefore increasing the incidence of this species in the diet.

The frequency of sprainting areas emphasises the use of stones as sprainting sites. In the absence of stones, grass tussocks, branches close to the ground, and the ground itself may be used. Few spraints were found on stones in the river, but many were found in hover entrances, although in mnay cases, these were smears and no dietary analysis could be made.

The results for habitat type (Table 3) around the sprainting sites was very subjective since the classification of 'open' and 'cover' is very difficult. The restricted public access to the river Blyth site may allow otters to defaecate in fairly open areas and remain undisturbed, despite the adequate cover in the habitat as a whole. Much of the North Tyne was open and the animals have little choice for sprainting sites. 'Open' habitat may be only a few metres from bushes or long grass, so the animal would be able to escape if disturbed. The frequent use of hovers on the Blyth yielded the largest number of spraints from hover sites. The Wansbeck-Font with its absence of hovers showed a greater use of cover for sprainting sites, possibly because at some of the sites, disturbance occurs.

Erlinge (1969) found the prey items taken by otters and mink (Mustela vison) to be similar, but one third of the fish taken by the otter are species exceeding the maximum size of fish generally caught by mink. Wise (1978) found that the diets of the two mustelids overlapped most in autumn and winter.

The present study on otters compared to that of A. Rosser's on mink (pers.comm.) shows little overlap in the prey species taken on the North Tyne (see Appendix 2). The major prey in the minks' diet was found to be rabbit, with trout forming the major fish prey taken. Bird and mammal appeared much more frequently than in the otters diet, and overlapping of the feeding ecology appears to take place with the fish prey, mainly the salmonid species.Eel, the major prey of the otter are only taken in small amounts by the mink. The average length of trout taken by mink were 11.5cm (15.3cm otters diet) and it therefore seems that competition between the two mustelids is unlikely to occur, both through differences in prey sizes, and through the abundance of trout in the North Tyne. Erlinge, in his 1972 study, found that mink had a negative influence on the population size of the otter in Sweden because of food competition in winter, which caused restriction of the otter to sub-optimal habitats. The two mustelids were calculated as sharing food to a degree of approximately 30 - 40%. Otters are distinct ecologically, the otter being more adapted to the aquatic environment. The greater ecological amplitude of the mink has been supposed by Erlinge (1972), Day and Linn (1972) and Akande (1972) to allow the mink to occupy an ecological niche not previously fully exploited by indiginous carnivores. The relative abundance of mink on the North Tyne, compared to the relative scarcity of the otter population on all the watersheds is probably caused by disturbance. The absence of otters or a reduction in the population allows the mink to increase, but once established, on the North Tyne at least, they appear not to interfere with the otter. Mink are present on the Wansbeck-Font, but have been observed only rarely, and no scats were found.

Local naturalists regard Northumberland as one of the otter population strongholds in England. During the present study, evidence from fresh tracks and spraints suggest that throughout the watersheds, the otters range was extensive. The spraints collected from each of the three watersheds are probably produced by only one animal in each case and therefore indicates a lower population than is thought to be present. From the nature of the habitat on the rivers studied, one would expect a greater density of otters to occur, especially in areas where the disturbance is minimal, however, the large area required for the otters range may be fragmented by human interference and agricultural activities. However this study does show that otters are resident in Northumberland, and this year have been recorded breeding near the river Coquet. Action by the Otter Haven Project has secured havens for the otter in many areas of Northumberland including the Wansback and Font. Otter hunting was practised in this årea but now, due to the legal protection given the otter, that sport has ceased. River pollution in Northumberland is minimal except on the lower reaches of the Blyth, where discharge from the sewage works has damaged the fish populations, therefore the most likely cause of the low otter population is the detruction of the animals habitat and human interference.

In conclusion, the present study on the feeding ecology of the otter has demonstrated that the animals major prey types are fish, with mammal and bird being of minor importance. Crayfish and amphibia are taken where available locally. The fish are taken in proportion to their abundance and ability to escape. Further investigations in this study should include a greater sample of spraints, both from the watersheds and seasonally, so that any seasonal variation in the prey taken can be assessed and compared to previous research. It is essential to know the abundance and diversity of the prey populations and especially periods of local abundance such as breeding. With this knowledge, the understanding of the ecology of Lutra lutra could be increased, and therefore aid any future conservation of this endangered animal.

REFERENCES

Anon.(1969) The otter in Britain. Oryx 10 16-22.

Casteel. R.W. (1976). Fish remains in archeology and paleo-environmental studies. London: Academic Press.

Chanin. P.R.F.(1976). The ecology of the feral mink (Mustela vison) in Devon. Unpublished Ph.D. Thesis, University of Exeter.

Chanin.P.R.F. and Jefferies D.J. (1978). The decline of the otter (Lutra lutra) in Britain: an analysis of hunting records and discussion of causes. Biol.J.Linnean Soc.

Clapham. R.(1922) The book of the otter.London.

Coghill.I.(1978) The status of the otter (Lutra lutra) in Worcestershire. Worcs. Nat. Cons. Trust. Newsletter 23: 11-13.

Collier.W.P.(1908) Notes on the otter. The Zoologist 66: 92-96.

Corbet.G.B. and Southern.H.N. (1977) The Handbook of British Mammals. Blackwell Scientific Publications.

Cranbrook.Earl of.(1978) The status of the otter (Lutra lutra) in Britain in 1977. Biol.J.Linnean Soc.9 305-322.

Day.M.G.(1966) Identification of hair and feather remains in the gut and faeces of stoats and weasels. J.Zool. Lond. 148: 201-217.

Erlinge.S.(1967a) Home range of the otter(Lutra lutra) in Southern Sweden. Oikos 18: 186-209.

Erlinge.S.(1967b) Food habits of the fish otter (Lutra lutra) in Southern Swedish habitats. Viltrevy 4 371-438.

Erlinge.S.(1968a) Territoriality of the otter(Lutra lutra)L. Oikos 19: 81-98.

Erlinge.S.(1968b) Food studies in captive otters.Oikos 19:259-270

Erlinge.S.(1969) Food habits of the otter(Lutra lutra)and the mink (Mustela vison)Schreber, in a trout water in Southern Sweden. Oikos 20: 1-7.

Erlinge.S.(1972a) The situation of the otter in Sweden.Viltrery 8: 379-397.

Erlinge.S.(1972b) Interspecific relations between the otter (Lutra lutra)and mink,(Mustela vison)in Sweden. Oikos 23: 327-335

Elmhirst.R.(1938) Food of the otter in the marine tidal zone. Scott.Nat.:99-102.

Fairley.J.S.(1972) Food of otters (Lutra lutra)from Co. Galway, Ireland, and notes on other aspects of their biology.J.Zool.Lond.166: 469-474.

Fairley.J.S.and Wilson.S.C. (1972) Autumn food of the otter(Lutra lutra)on the Argivey river,Co.Londonderry.Northern Ireland. J.Zool.Lond. 166: 469-479.

Freshwater Biological Ass. (1979) Unpublished report of the Teesdale Unit No.2.

Gorman.M.L.Jenkins.D.Harper. R.J.(1978) Anal scent sacs of otters. J.Zool.Lond.186: 463-474.

Greer.K.R.(1955) Yearly food habits of the river otter in the Thompson Lakes region N.W.Montana, as indicated by scat analysis.Amer.Midl.Nat. 54: 299-313.

Harris.C.J.(1968) Otters, a study of the recent Lutrinae. London Weidenfield and Nicholson.

Hewer.H.R.(1974) Otters in Britain, a second report. Oryx 12: 429-435.

Hewson.R.(1969) Couch building by otters(Lutra lutra)J.Zool.Lond. 159: 524-527.

Hewson.R.(1973) Food and feeding habits of otters (Lutra lutra) at Loch Park, N.E.Scotland. J.Zool.Lond. 170: 159-162.

Hewson.R.and Kruuk.H.(1978) Spacing and foraging of otters(Lutra lutra) in a marine habitat. J.Zool.Lond.185: 205-212.

Jenkins.D.,Walker.J.G.K., and McCowan.D.(1979) Analysis of otter faeces from Deeside,N.E. Scotland. J.Zool.Lond. 187: 235-244.

Jones.A.,Bray.R.P. and Wood.M.S.(1979) Editors of the Otter Survey of Wales 77-78. Published by NCC/SPNC.

King.A.,Ottaway.J.,Potter.A. (1976) The declining otter, a guide to its conservation.Friends of the Earth Campaign.

Knudson.G.J. and Hale.J.B. (1968) Food habits of otters in the Great Lakes Region.J.Wildlife Man.32: 89-93.

Lagler.K.F. and Ostenson.B.T. (1942) Early spring food of the otter in Michegan. J.Wildlife Man. 6: 244-254.

Liers.E.E.(1951) Notes on the river otter. J.Mamm 32: 1-9.

Lockie.J.D.(1959) The estimation of the food of foxes. J.Wildlife Man. 23: 224-227.

Maitland.P.S.(1972) A key to the freshwater fishes of the British Isles. F.B.A. Windermere.

MacArthur.R.H.,and MacArthur J.W.(1961) On bird species diversity. Ecology 42.

MacDonald.S. and Mason.C.F. (1976) The status of the otter (Lutra lutra) in Norfolk Biol.Conservation 9: 119-124.

MacDonald.S.and Mason.C.F. and Coghill.I.S.(1978) The otter and its conservation in the River Teme catchment. J.Appl.Ecol. 15: 373-384.

O'Connor.F.B.,Sands.T.S., Barwick.D.,Chanin.P.R.F., Frazer.J.F.D.,Jefferies.D.J., Jenkins.D. and Neal.E.G.(1977) Otters 1977. First report of the joint NCC/SPNC otter group London.

Northumbrian Water Authority. Fisheries report for the year - 1979.

Preble.E.A.(1908) A Biological Investigation of the Athabasca-Mackenzie Region. N.Am. Fauna. 27: 228.

Quigley.M.(1977) Invertebrates of streams and rivers.Edward Arnold.

Rowbottom.J.(1969) Watching otters in Scotland. Animals.12: 159-161.

Rowe.D.,and Rowe.T.(1977) Food ecology of otters in Natal. S.Africa. Oikos.28: 210-219.

Ryder.R.A.(1955) Fish predation by the otter in Michegan. J.Wildlife Man. 19: 497-498.

Sheldon.W.G. and Toll.W.G. (1964) Feeding habits of the river otter in a reservoir in Central Massachussets. J.Mamm. 45 (3): 449-455.

Shephard.S.(1937) The otters of Norfolk. Trans.Norf.Norwich Nat.Soc.14: 138-142.

Southern.H.M.(ed)(1964) The Handbook of British Mammals. Oxford. Blackwell.

Stephens.H.M.(1957) The Natural History of the Otter.U.F.A.W.

Toweill.D.E.(1974) Winter food habits of river otters in Western Oregon.J.Wildlife Man. 38: 107-111.

Veen.J.(1975) The occurrence and behaviour of the fish otter (Lutra lutra) in North Holland.Lutra 17: 21-37.

Weir.V.and Bannister.K.E. (1977) Additional notes on the food of the otter in the Blakeney area, Norfolk. Trans.Norf.Norw. Nat.Soc. 24:85-88.

West.R.B.(1975) Suffolk Otter Survey. Suffolk Natural History 16: 378-388

Wise.M.H.(1978) The feeding ecology of otters and mink in Devon. Unpub. Ph.D. Thesis. University of Exeter.

Wise.M.H.(1980) The use of vertebrae in scats for estimating prey size of otter and mink.J.Zool.Lond. 192: 25-32.

SUMMARY.

The feeding ecology of the otter was studied on three Northumbrian watersheds, the North Tyne, the Blyth, and the Wansbeck-Font. Otter faeces (spraints) were collected and examined for prey remains, keys, photographs and reference collections were used for identification of the prey, and where possible, back calculations of fish sizes were attempted. Methods of data analysis included frequency and bulk analysis.

(1) Results show that fish form the major prey taken by otter.

(2) Amphibia are of secondary importance on the North Tyne and crayfish on the Blyth and Wansbeck-Font watersheds.

(3) Eel is the major prey species taken on the North Tyne, followed by salmonid and stone loach. There was only one occurrence of bird or mammal. No crayfish were found in the diet.

(4) Eel was the major prey on the Blyth, with stone loach and Cyprinidae of secondary importance. Crayfish were present in spraints but amphibia were absent.

(5) Bullhead forms the major prey on the Wansbeck-Font watershed. Trout, Cyprinidae and stone loach were also frequent prey along with crayfish.

(6) In general, the prey taken was similar in size for each species, although eel and perch were significantly larger on the Wansbeck-Font.

(7) Seasonal data tentatively suggests a reduction in trout, crayfish, amphibia, Cyprinidae and perch in the summer diet compared with that in the spring, but this may reflect local variations.

(8) Evidence from research on the feeding ecology of mink by A. Rosser (pers. comm.) shows little overlap in the diets and it is therefore concluded that competition between the two mustelids is insignificant.

APPENDICES

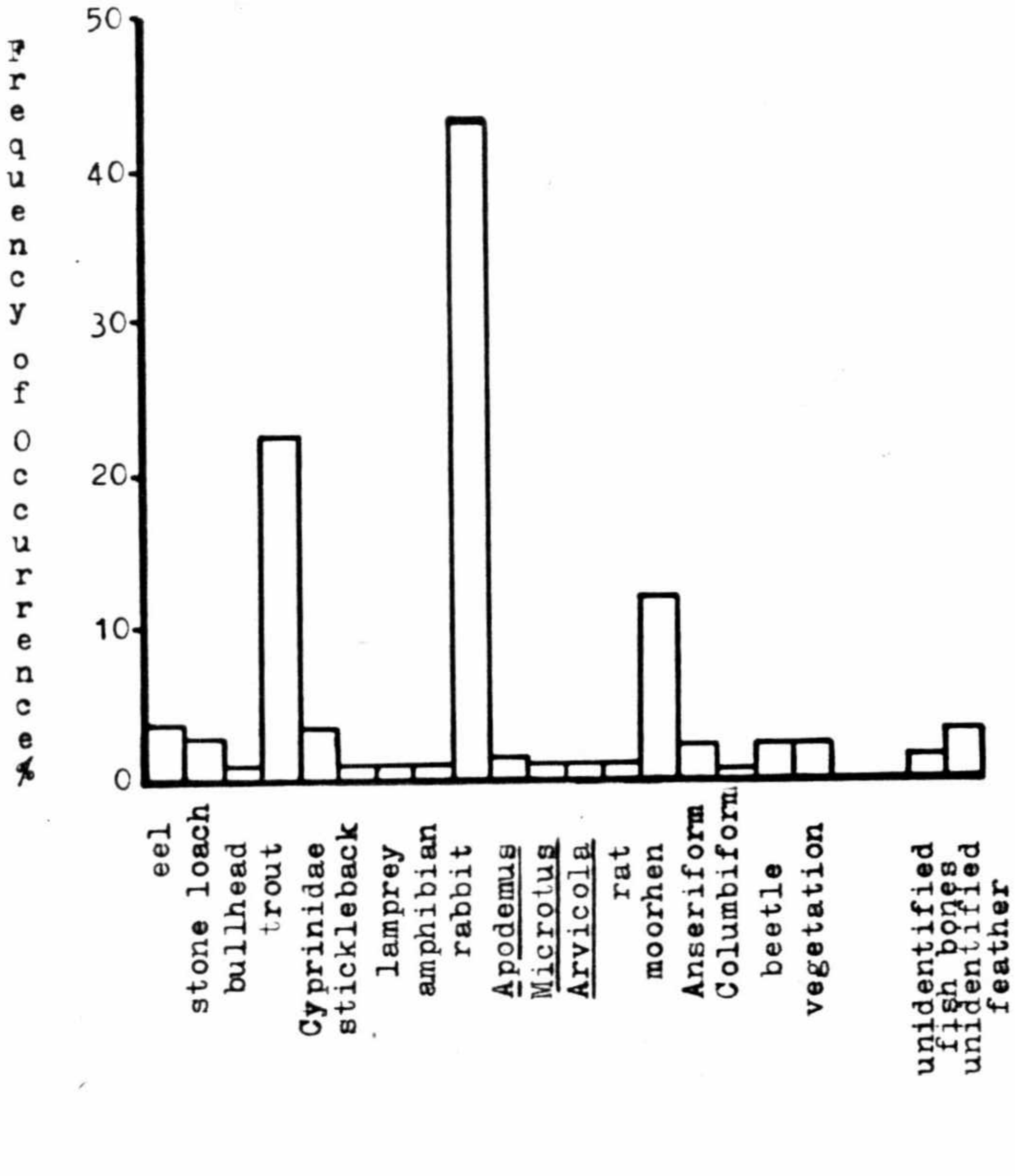
APPENDIX 1. RELATIVE FREQUENCY OF OCCURRENCE OF PREY ITEMS IN THE DIET OF OTTERS ON THE THREE WATERSHEDS.

PREY ITEM	% Relative frequency of occurrence.		
	N.T.	B.	W/F.
eel	41.1	36.7	3.4
perch	0.8	3.8	4.0
stone loach	12.9	24.1	13.7
bullhead	4.8	7.6	29.1
salmonid	19.4	5.1	16.2
Cyprinidae	4.0	11.4	12.0
stickleback	1.6	6.3	4.3
pike	3.2	-	-
Thymallidae	0.8	-	-
crayfish	-	3.8	12.8
amphibian	9.7	-	4.3
moorhen	0.8	-	0.9
Apodemus	0.8	-	-

N.T. = North Tyne
B. = Blyth
W/F. = Wansbeck - Font.

APPENDIX 2. FREQUENCY OF OCCURENCE OF PREY ITEMS IN THE DIET OF MINK ON THE NORTH TYNE WATERSHED.

(A.Rosser 1980)



ACKNOWLEDGEMENTS

Firstly I should like to thank the Natural Environmental Research Council for the grant, without which this study could not have been made, and the various landowners who kindly gave permission to survey the sites.

I am also indebted to my tutor, Dr Nigel Dunstone, who gave help and guidance throughout the study, I am also grateful for the data on fish stocking and river flow from the N.E. Water Authority, especially Bill Walker.

Thanks to Keith Elliot of the Otter Haven Project and to Hugh Watson whose extensive knowledge of otter habits proved invaluable. Useful information and help was kindly given by James Mullins (gamekeeper to the Chester's estate, Chollerford) and the secretaries of the various angling clubs around the region. Fish for the reference collections were kindly supplied by the Blue Circle Cement Works (Fish Division) County Durham, and the Moorland Trout Farms, Pickering. I should like to thank Margaret Wise for permission to use her data on fish length. I am grateful to Iris Hunter who diligently typed this work, and to Tim, for moral support and encouragement, and for keeping my car on the road.

Thanks to Alison Rosser who helped by collecting some spraints during her mink survey of the North Tyne, and finally to my M.Sc., colleagues whose criticisms and encouragement were always gratefully received.